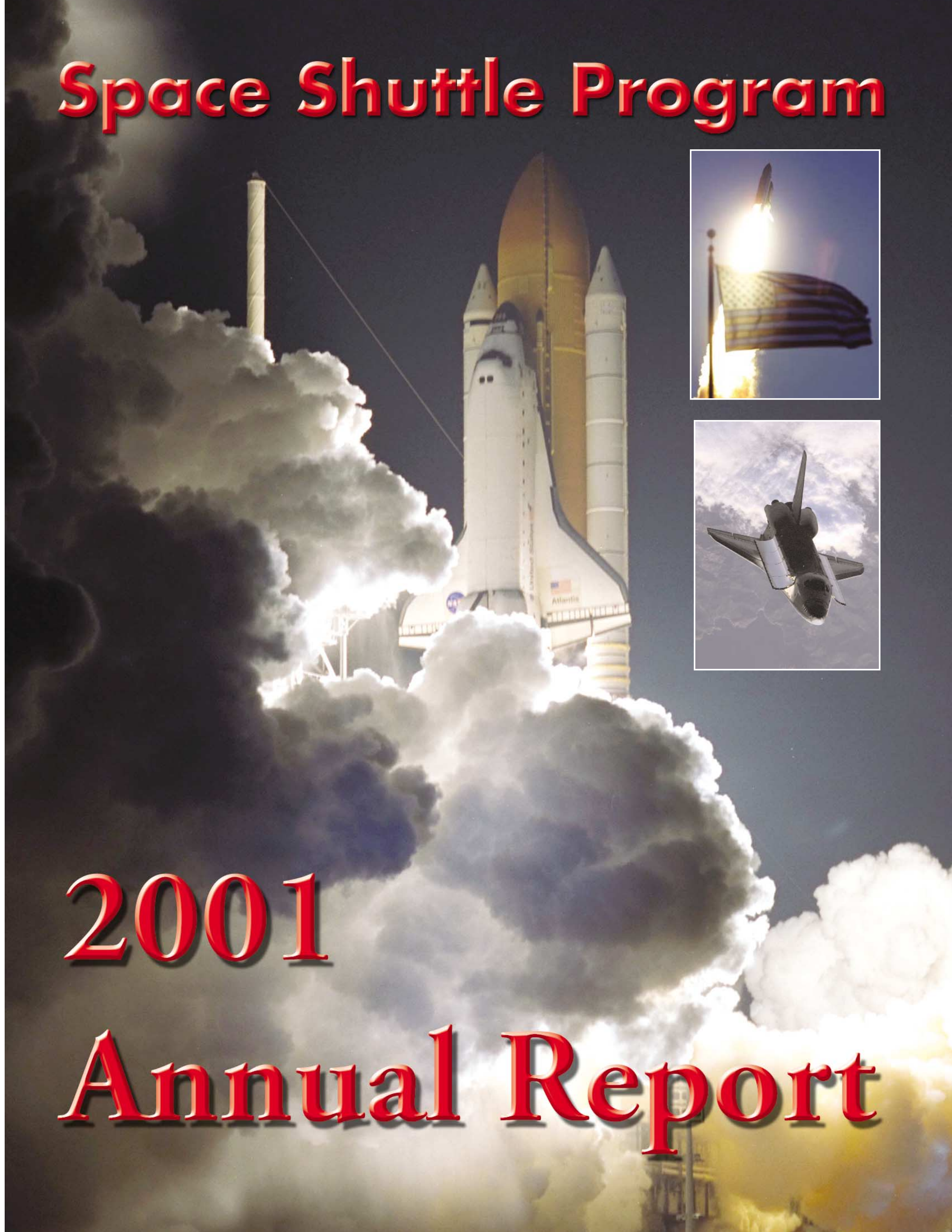
Space Shuttle Program



2001 Annual Report

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Ronald D. Dittemore,
Manager, Space Shuttle Program

A Banner Year for the Space Shuttle

We have flown seven flawless missions in FY2001, starting with STS-92 in October and finishing with STS-105 in August. These seven flights, dedicated to the construction of the International Space Station (ISS), delivered more than 45 tons of hardware. From the launch of STS-98 in February to the landing of STS-105 in August, we have flown five flights in 6 months, maintaining a vehicle in orbit for more than one-third of that time. This is a great tribute to the expertise and diligence of the entire Space Shuttle team.

FY2002 will be just as demanding and exciting as this past year, with seven launches scheduled. Included in the manifest are five complex ISS missions, an extended-duration research mission, and a Hubble Space Telescope re-servicing mission with five scheduled extravehicular activites.

Increased awareness of process control was again emphasized this year, with the directed focus beginning to show significant improvements. In addition, independent audits of the Logistics, External Tank, Reusable Solid Rocket Motor, Space Shuttle Main Engine, and Solid Rocket Booster projects reinforced our belief that the program maintains robust, sound processes.

Safety and risk management have continued to be a major focus in the Space Shuttle Program (SSP). We have taken the leadership role in the development of a more useful probabilistic risk assessment (PRA) tool to aid in program decision-making. This effort is well under way, with a complete systems PRA scheduled for release in March 2003. Initial phases of this software tool have already been used to evaluate upgrade candidates, and it is proving to be a valuable tool.

The Industrial Engineering for Safety (IES) initiative is making dramatic improvements in risk reduction. This initiative, designed to evaluate and implement modifications to reduce workforce and collateral damage risk, currently has 25 funded projects and several more in study.

FY2001 has also been a year of challenges and change. Maintaining the long-term safety and viability of the SSP has been the focus of the SSP management team. The transition from NASA oversight to insight associated with contract consolidation, and the continuing loss of NASA skills and experience have the potential to erode the critical checks and balances within the program. A "Concept of Privatization of the Space Shuttle Program" was developed to address the erosion of critical checks and balances, and the SSP management team is continuing to evaluate several options to maintain program robustness, all centered around the merger of the talented workforces of NASA and the contractor community.

> "*Some people face the past and back into the future. We need to face the future and press forward.*"
>
> – Former Secretary of State George Schultz

We have made significant progress in FY2001, and the entire SSP workforce should be extremely proud of these great accomplishments. It has been a banner year for the SSP. We have a tremendously talented team ready to "face the future and press forward." ◆

Goal 1 ❖ Fly Safely

Since returning to flight in 1988, the SSP has had an outstanding safety record and significant progress has been made in improving the reliability of some of its major components. Our goal is to ensure that this legacy continues by investing in upgrades that embrace advanced technologies that improve reliability while assuring safety.

Goal 2 ❖ Meet the Manifest

Meeting the ISS challenge of assembling the most complex space structure ever created requires the SSP to be responsive to mission-specific manifest changes. Space Shuttle planning must be flexible to accommodate the ISS changes while also maintaining the schedules of our non-ISS customers. Along with ISS missions, the Space Shuttle will continue to provide scientific and research missions with continued, reliable human access to space.

Goal 3 ❖ Improve Mission Supportability

The ISS mission requirements place an increased demand on the Space Shuttle systems. The assembly process will require an unprecedented number of extravehicular activities, rendezvous and docking, and remote manipulator system activities as well as many other new challenges inherent in a mission of this grand scale. To meet these demands, a series of supportability upgrades are being developed to increase Space Shuttle performance and system capability.

Goal 4 ❖ Improve the System

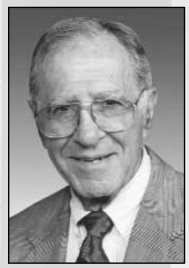
The SSP has a goal of continuously improving its developmental and operational processes, making them more effective and efficient. The Space Shuttle will fundamentally be the workhorse that builds the ISS. This will require a sustained flight rate to adequately support the assembly sequence. This will be accomplished through a combination of reductions in the flight preparation and postflight hardware refurbishment times, and faster reconfiguration of operational support facilities. As processes are improved and upgrades are incorporated, the Space Shuttle's capabilities will increase, reducing the cost of access to low Earth orbit and providing increased access to the space community.

Space Shuttle Program Senior Management

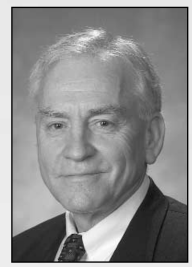
Ronald D. Dittemore
Manager, Space Shuttle Program (JSC)

Linda J. Ham
Manager
Program Integration (JSC)

James D. Halsell
Manager
Launch Integration (KSC)



Alex A. McCool
Manager
MSFC Projects (MSFC)



Elric N. McHenry
Manager, Space Shuttle
Development (JSC)

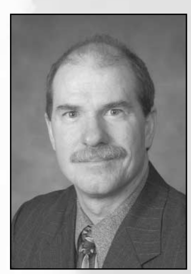
Ralph R. Roe
Manager, Vehicle
Engineering (JSC)

James B. Costello
Manager, Business
Office (JSC)

Joyce Rozewski
Manager, Industrial
Engineering (KSC)

Lambert D. Austin
Manager, Systems
Integration (JSC)

Michele A. Brekke
Manager, Customer and
Flight Integration (JSC)



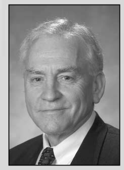
William J. Harris
Manager, Safety and
Mission Assurance (JSC)

Ronald D. Dittemore
Manager, Space Shuttle Program (JSC)

Linda J. Ham
Manager
Program Integration (JSC)

James D. Halsell
Manager
Launch Integration (KSC)

Alex A. McCool
Manager
MSFC Projects (MSFC)



Elric N. McHenry
Manager
Space Shuttle Development (JSC)

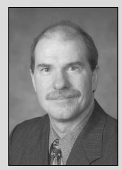
Ralph R. Roe
Manager, Vehicle
Engineering (JSC)

SSP Senior Management

Lambert D. Austin
Manager, Systems
Integration (JSC)

Michele A. Brekke
Manager, Customer and
Flight Integration (JSC)

James B. Costello
Manager, Business
Office (JSC)



William J. Harris
Manager, Safety and
Mission Assurance (JSC)

Joyce Rozewski
Manager, Industrial
Engineering (KSC)

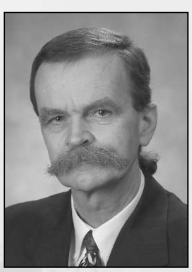
Steve Hawley
Director
Flight Crew Operations (JSC)

Jon C. Harpold
Director
Mission Operations (JSC)

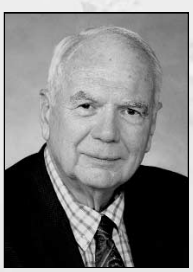
David A. King
Director
Shuttle Processing (KSC)

Anne Gawronski
Logistics (KSC)

Joan Baker
Technical Assistant to the
SSP Manager

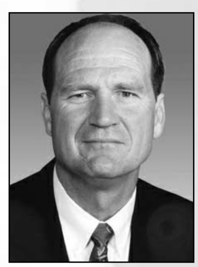


David A. Hamilton,
Chairman, Chief
Engineers Council (JSC)



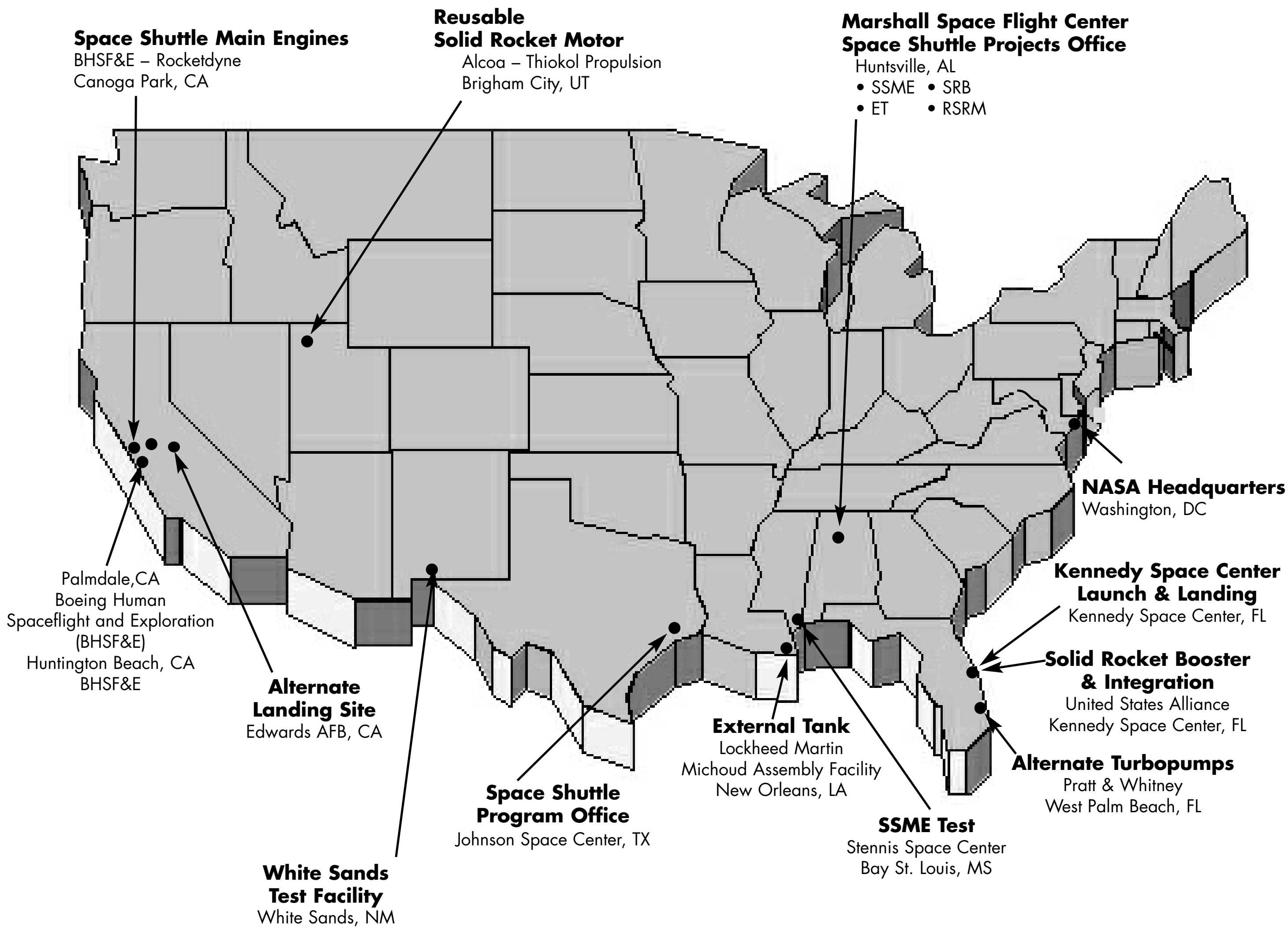
George D. Hopson
Manager, Space Shuttle Main
Engine (MSFC)

Parker V. Counts
Manager, Solid Rocket
Booster (MSFC)



Michael U. Rudolphi
Manager, Reusable Solid Rocket
Motor (MSFC)

Jerry W. Smelser
Manager
External Tank (MSFC)


Space Shuttle Main Engines
BHSF&E – Rocketdyne
Canoga Park, CA
Reusable
Solid Rocket Motor
Alcoa – Thiokol Propulsion
Brigham City, UT
Marshall Space Flight Center
Space Shuttle Projects Office
Huntsville, AL
• SSME • SRB
• ET • RSRM
NASA Headquarters
Washington, DC
Kennedy Space Center
Launch & Landing
Kennedy Space Center, FL
Solid Rocket Booster
& Integration
United States Alliance
Kennedy Space Center, FL
Alternate Turbopumps
Pratt & Whitney
West Palm Beach, FL
Palmdale,CA
Boeing Human
Spaceflight and Exploration
(BHSF&E)
Huntington Beach, CA
BHSF&E
Alternate
Landing Site
Edwards AFB, CA
External Tank
Lockheed Martin
Michoud Assembly Facility
New Orleans, LA
Space Shuttle
Program Office
Johnson Space Center, TX
SSME Test
Stennis Space Center
Bay St. Louis, MS
White Sands
Test Facility
White Sands, NM

106 Total Flights

81 Since Return to Flight

Legend

Flt. No.	STS-XX No.	Launch – Landing Date Date

After 51-L (white)
Before 51-L (Flight-25) (gray)

Number of Flights: 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

25	51-L	1/28/86
22	61-A	10/30/85-11/06/85
19	51-F	7/29/85 - 8/06/85
17	51-B	4/29/85 - 5/06/85
13	41-G	10/05/84 - 10/13/84
11	41-C	4/06/84 - 4/13/84
10	41-B	2/03/84 - 2/11/84
8	8	8/30/83 - 9/05/83
7	7	6/18/83 - 6/24/83
6	6	4/04/83 - 4/09/83

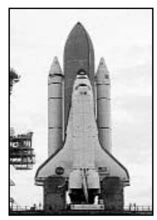
Challenger
OV-099

95	93	7/23/99 - 7/27/99
90	90	4/17/98 - 5/03/98
88	87	11/19/97 - 12/05/97
85	94	7/01/97 - 7/17/97
83	83	4/04/97 - 4/08/97
80	80	11/19/96 - 12/07/96
78	78	6/20/96 - 7/07/96
75	75	2/22/96 - 3/09/96
72	73	10/20/95 -11/05/95
63	65	7/08/94 -7/23/94
61	62	3/04/94 - 3/18/94
58	58	10/18/93 - 11/01/93
55	55	4/26/93 - 5/06/ 93
51	52	10/22/92 - 11/01/92
48	50	6/25/92 - 7/09/92
41	40	6/05/91 - 6/14/91
38	35	12/02/90 - 12/10/90
33	32	1/09/90 - 1/20/90
30	28	8/08/89 - 8/13/89
24	61-C	1/12/86 - 1/18/86
9	41-C	1/28/83 - 12/08/83
5	5	11/11/82 - 11/16/82
4	4	6/27/82 - 7/04/82
3	3	3/22/82 - 3/30/82
2	2	11/12/81 - 11/14/81
1	1	4/12/81 - 4/14/81

Columbia
OV-102

106	105	8/10/01 - 8/22/01
103	102	3/07/01 - 3/20/01
100	92	10/11/00 -10/24/00
96	103	12/19/99 - 12/27/99
94	96	5/27/99 - 6/06/99
92	95	10/29/98 - 11/7/98
91	91	6/02/98 - 6/12/98
86	85	8/07/97 - 8/19/97
82	82	2/11/97 - 2/21/97
70	70	7/13/95 - 7/22/95
67	63	2/03/95 - 2/11/95
64	64	9/09/94 - 9/20/94
60	60	2/03/94 -2/11/94
57	51	9/12/93 -9/22/93
54	56	4/08/93 - 4/17/93
52	53	12/02/92 - 12/09/92
45	42	1/22/92 - 1/30/ 92
43	48	9/12/91 - 9/18/91
40	39	4/28/91 - 5/06/91
36	41	10/06/90 -10/10/90
35	31	4/24/90 - 4/29/90
32	33	11/22/89 - 11/27/89
28	29	3/13/89 - 3/18/89
26	26	9/29/88 - 10/03/88
20	51-I	8/27/85 - 9/083/85
18	51-G	6/17/85 - 6/24/85
16	51-D	4/12/85 - 4/19/85
15	51-C	1/24/85 - 1/27/85
14	51-A	11/07/84 - 11/15/84
12	41-D	8/30/84 - 9/04/84

Discovery
OV-103

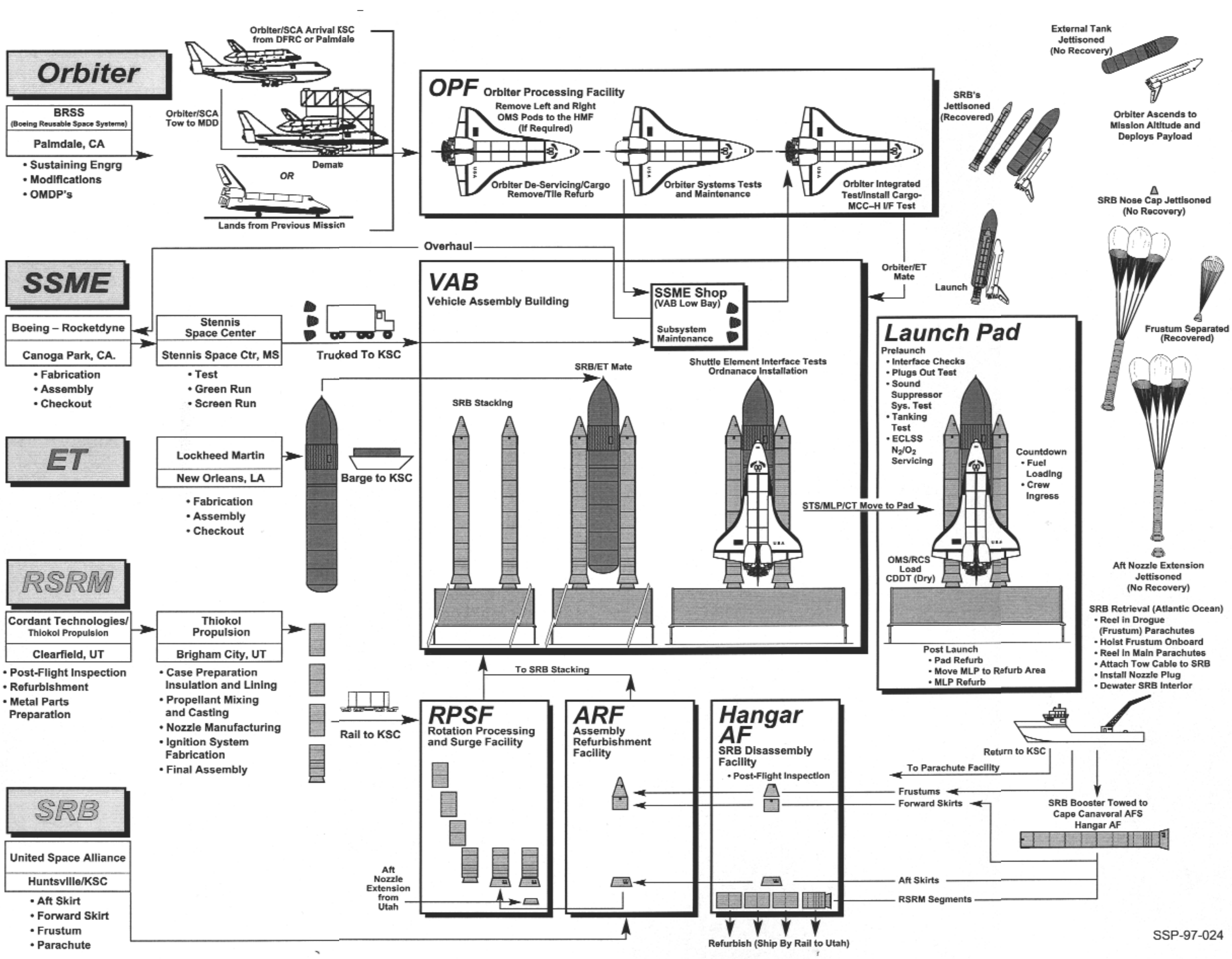


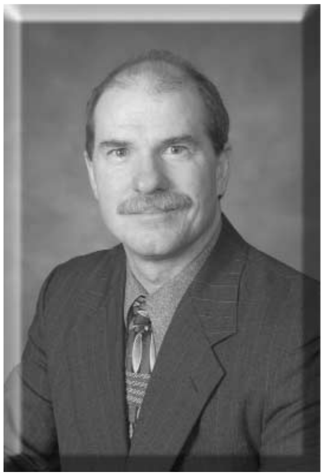
105	104	7/12/01 - 7/24/01
102	98	2/07/01- 2/20/01
99	106	9/08/00 - 9/20/00
98	101	5/19/00 - 5/29/00
87	86	9/25/97 - 10/06/97
84	84	5/15/97 - 5/24/97
81	81	1/12/97 - 1/22/97
79	79	9/16/96 - 9/26/96
76	76	3/22/96 - 3/31/96
73	74	11/12/95 - 11/20/95
69	71	6/27/95 - 7/07/95
66	66	11/03/94 - 11/24/94
49	46	7/31/92 - 8/08/92
46	45	3/24/92 - 4/02/92
44	44	11/24/91 - 12/02/91
42	43	8/02/91 - 8/11/91
39	37	4/05/91 - 4/11/91
37	38	11/15/90 - 11/20/90
34	36	2/28/90 - 3/04/90
31	34	10/18/89 - 10/23/89
29	30	5/04/89 - 5/08/89
27	27	12/02/88 - 12/06/88
23	61-B	11/26/85 - 12/03/85
44	51-J	10/03/85 - 10/07/85

Atlantis
OV-104

104	100	4/19/01 - 5/01/01
101	97	10/11/00 - 10/24/00
97	99	2/11/00 -2/22/00
93	88	12/04/98 -12/15/98
89	89	1/22/98 - 1/31/98
77	77	5/19/96 - 5/29/96
74	72	1/11/96 - 1/20/96
71	69	9/07/95 - 9/18/95
68	67	3/02/95 - 3/18/95
65	68	9/30/94 - 10/11/94
62	59	4/09/94 - 4/20/94
59	61	12/02/93 - 12/13/93
56	57	6/21/93 - 7/01/93
53	54	1/13/93 - 1/19/93
50	47	9/12/92 - 9/20/92
47	49	5/07/92 - 5/16/92

Endeavour
OV-105


Orbiter
BRSS
(Boeing Reusable Space Systems)
Palmdale, CA
• Sustaining Engrg
• Modifications
• OMDP's
Orbiter/SCA Arrival KSC from DFRC or Palmdale
Orbiter/SCA Tow to MDD
Demate
OR
Lands from Previous Mission
OPF Orbiter Processing Facility
Remove Left and Right OMS Pods to the HMF (If Required)
Orbiter De-Servicing/Cargo Remove/Tile Refurb
Orbiter Systems Tests and Maintenance
Orbiter Integrated Test/Install Cargo-MCC–H I/F Test
SRB's Jettisoned (Recovered)
External Tank Jettisoned (No Recovery)
Orbiter Ascends to Mission Altitude and Deploys Payload
SRB Nose Cap Jettisoned (No Recovery)
Overhaul
Orbiter/ET Mate
Launch
SSME
Boeing – Rocketdyne
Canoga Park, CA.
• Fabrication
• Assembly
• Checkout
Stennis Space Center
Stennis Space Ctr, MS
• Test
• Green Run
• Screen Run
Trucked To KSC
VAB
Vehicle Assembly Building
SSME Shop (VAB Low Bay)
Subsystem Maintenance
SRB/ET Mate
SRB Stacking
Shuttle Element Interface Tests Ordnanace Installation
STS/MLP/CT Move to Pad
Launch Pad
Prelaunch
• Interface Checks
• Plugs Out Test
• Sound Suppressor Sys. Test
• Tanking Test
• ECLSS N_2/O_2 Servicing
Countdown
• Fuel Loading
• Crew Ingress
OMS/RCS Load CDDT (Dry)
Post Launch
• Pad Refurb
• Move MLP to Refurb Area
• MLP Refurb
Frustum Separated (Recovered)
Aft Nozzle Extension Jettisoned (No Recovery)
SRB Retrieval (Atlantic Ocean)
• Reel in Drogue (Frustum) Parachutes
• Hoist Frustum Onboard
• Reel in Main Parachutes
• Attach Tow Cable to SRB
• Install Nozzle Plug
• Dewater SRB Interior
ET
Lockheed Martin
New Orleans, LA
• Fabrication
• Assembly
• Checkout
Barge to KSC
RSRM
Cordant Technologies/ Thiokol Propulsion
Clearfield, UT
• Post-Flight Inspection
• Refurbishment
• Metal Parts Preparation
Thiokol Propulsion
Brigham City, UT
• Case Preparation Insulation and Lining
• Propellant Mixing and Casting
• Nozzle Manufacturing
• Ignition System Fabrication
• Final Assembly
Rail to KSC
To SRB Stacking
RPSF
Rotation Processing and Surge Facility
ARF
Assembly Refurbishment Facility
Hangar AF
SRB Disassembly Facility
• Post-Flight Inspection
Return to KSC
To Parachute Facility
Frustums
Forward Skirts
SRB Booster Towed to Cape Canaveral AFS Hangar AF
Aft Skirts
RSRM Segments
Aft Nozzle Extension from Utah
Refurbish (Ship By Rail to Utah)
SRB
United Space Alliance
Huntsville/KSC
• Aft Skirt
• Forward Skirt
• Frustum
• Parachute
SSP-97-024



William J. Harris, Manager, Safety and Mission Assurance (JSC)

Employee Commitment Drives Unprecedented Safety Record…

Significant emphasis is placed on the protection of the public, the crews, the workforce, and the hardware. The safety record of the Space Shuttle is a testimony to the skill and commitment of the Space Shuttle Program (SSP) Team.

Quantitative Risk Assessment

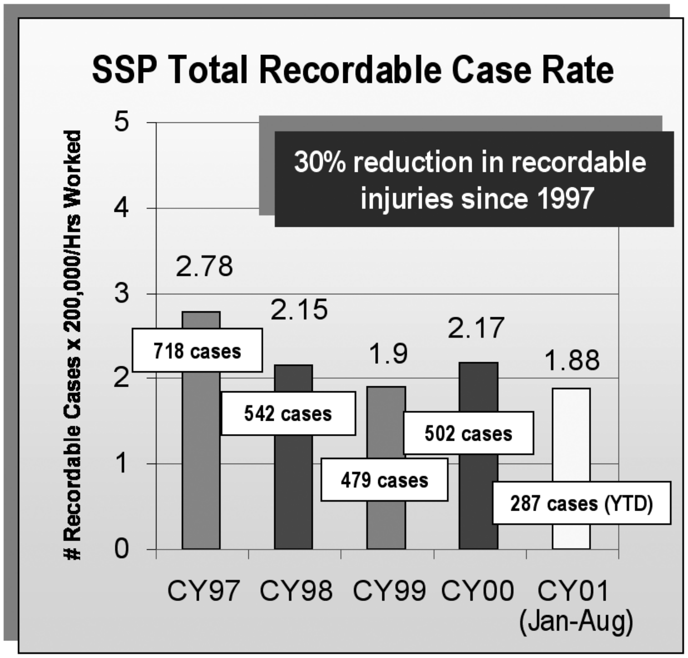
The SSP is aggressively evaluating and developing the implementation of quantitative risk assessment methods. The Shuttle System Safety Review Panel (SSRP) has been leading the combined efforts of multiple NASA centers and element contractors in developing the Space Shuttle probabilistic risk assessment (PRA). The Space Shuttle PRA will provide quantitative risk information to aid in program decision-making. PRA techniques have already been used extensively to evaluate the risk impacts of system modifications and upgrades. Other PRA applications have included evaluation of risk reduction using the main engine advanced health monitoring system (AHMS) and the risk tradeoff of extending the Space Shuttle nose gear versus designing more robust tires. With the PRA model, analysts can identify risk contributions and relationships down to the system and piece part level. The first release of the Space Shuttle PRA, which is planned for March 2003, will model the vehicle from launch through landing.

Aerospace Technician Certification Program

The SSP has been active in the further development and recognition of workforce skills. The Aerospace Technician Certification Program is a joint effort with participation by NASA, industry, and a consortium of schools from across the country to establish certification of aerospace technicians to a higher standard than currently exists. The program makes use of a specialized curriculum and state-of-the-art instructional techniques to provide a pool of "work-ready" employees for the Space Shuttle and other aerospace programs. Brevard Community College (BCC) led the implementation effort and has commenced classes at the BCC facilities located inside the Kennedy Space Center (KSC) Center for Aerospace Education. In addition to technical support and guidance for the overall program, the United Space Alliance (USA) is providing full scholarship funding for several participants in this initial class. Congressional and Florida state government support for this initiative has been outstanding.

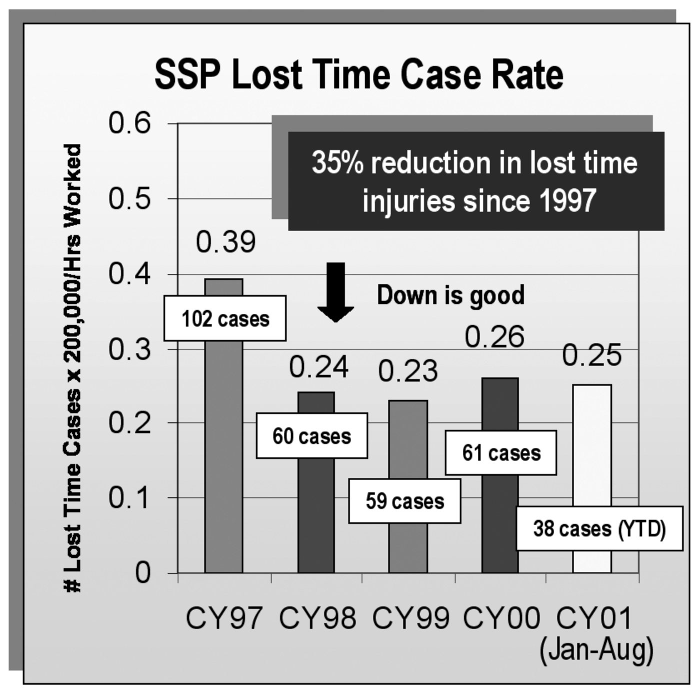
Safety

Management commitment and employee involvement continue to be the driving influence in



improving safety in the workplace. Fewer employees have been injured on the job as a result of the emphasis placed on safety. The Total Recordable Case Rate and the Lost Time Case Rate have both dropped dramatically since 1997. In addition, there have been no Type A or B property damage mishaps this year, demonstrating a commitment to the safe handling of spaceflight hardware. Type C property damage mishaps are down by 40%.

The Space Shuttle Program Safety community is communicating more than ever before, sharing lessons learned and best practices that make the SSP even better. Senior safety managers representing USA, Boeing - Rocketdyne, Lockheed Martin, ATK Thiokol, Pratt & Whitney, and Hamilton Sunstrand have collectively formed the SSP Contractor Safety Council. This Council meets on a regular basis to work safety issues that are common to the SSP. The Council's charter establishes a technical forum focused on understanding issues that impact programmatic safety and identifing initiatives designed to improve performance. An essential aspect of the Council is the ability to identify lessons learned and share best practices across the SSP Team. The Council provides a valuable source of experience and subject matter expertise that will result in improved safety for the entire SSP. ◆



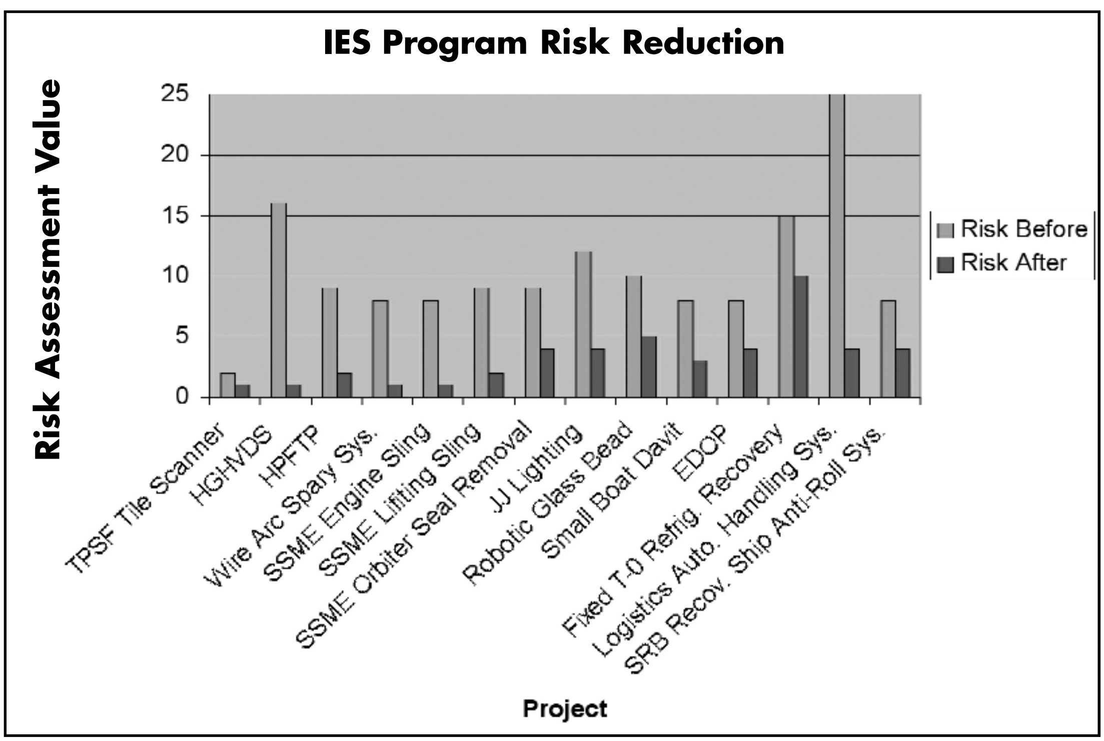
IES Improves Workplace Safety, Reduces Risk to Hardware…

Joyce Rozewski, Manager, Industrial Engineering (KSC)

This initiative encourages increased use of industrial engineering methods across the Space Shuttle Program (SSP), ensuring that maintainability and human factors elements are adequately considered in new designs. The Industrial Engineering for Safety (IES) initiative is in the second year of the planned 5-year project, and currently has 25 projects and 8 studies funded.

These projects include large-scale efforts such as the Enhanced Diver Operated Plug for Booster Rewatering that results in reduced diver workload and time at depth, improves plug installation, and automates the locking mechanism, to smaller scale projects such as one to improve the handle on the main engine fuel pump to reduce the potential for damage or injury.

The dramatic improvements in risk reduction can be seen in the chart at right. The IES initiative will continue to define and implement projects to improve personnel and hardware safety.



Process Control

The Process Control Focus Group continues to actively promote process control awareness and improvements across the SSP. The SSP has been recognized by government and industry as the leader in the area of process control, and the focus group continues to break new ground in finding ways to reduce process escapes that could result in mission failure or loss of life.

The group's mission is to reduce program risk by preventing process escapes. This is being accomplished by raising awareness of the process control issue and motivating culture change within the supplier base, which consists of thousands of suppliers across the country. The awareness program has been very successful. A comprehensive marketing program was developed to target the supplier base with a variety of products that are complementary in reinforcing the process control message. Suppliers are getting the process control message through increased visits by prime contractors, and through supplier conferences and symposiums that focus on process control. Two videos, released by the Process Control Focus Group, have been distributed widely throughout the supplier base, with 1,400 suppliers and over 10,000 employees having watched the easy-to-understand process escape lessons in the first video, "Success in Process Control." This video received a Bronze Telly award for superior quality in production. The second video, "Countdown: Process Creep," is set to follow this year with similar wide distribution. Posters, brochures, supplier-specific product fact sheets, CD-ROM mini discs, and websites are additional tools being used to reach supplier employees at the personal level.

A controlling Shuttle Program Process Control Management Plan governs the Process Control Program. Over the last year, each of the Space Shuttle prime contractors has developed internal process control implementation plans to respond to the Space Shuttle mandate. The organizations are changing their culture to promote and integrate process control as a part of everyday business, and over this year all of the primes have instituted several new best practices to improve process control within their organizations and at their suppliers. Open sharing and communication of best practices through the Process Control Focus Group have stimulated significant cross-pollination of good process control tools and practices among the primes. For example, as a result of this sharing, all of the primes now have adopted a Stamp Warranty program as a best practice .

The efforts of the focus group are showing results. This year several of the prime contractors have shown marked reductions in process escapes and supplier nonconformances. This is a trend that the SSP will strive to continue through the efforts of the Process Control Focus Group. ◆

James B. Costello
Manager, Business Office (JSC)

Space Shuttle Program Meets Fiscal Challenges…

The Space Shuttle Program (SSP) was able to overcome numerous unprecedented cost challenges this fiscal year, including critical infrastructure revitalization requirements, Orbiter maintenance down period cost growth, significant economic rate impacts, and cost growth due to business base decline and critical skills requirements in several program areas. Several of these challenges will continue to affect the program through the budget horizon and will need continual management attention. Several safety upgrades have been funded this fiscal year, moving from the definition to the implementation phase. ◆

National Aeronautics and Space Administration
Space Shuttle Program
Financing and Operations
(for the years ending September 30, 2000 and 2001)
(In Millions)

	FY 2001	FY 2000
Financing Sources:		
Appropriated Capital	$3,323.3	$2,938.3
Reimbursables	$1.7	$24.8
Total Financing Sources	**$3,325.0**	**$2,963.1**
Shuttle Program Expenses:		
Ground Processing	$597.8	$532.3
Flight Operations	$189.0	$191.9
Aircraft / Flight Crew	$87.5	$60.1
Reusable Solid Rocket Motor	$389.7	$370.1
Solid Rocket Booster	$145.9	$140.5
External Tank	$346.2	$335.6
Space Shuttle Main Engine	$302.7	$272.3
SSME Test Support	$33.2	$31.6
Vehicle	$602.0	$493.9
Integrated Logistics	$204.8	$186.9
Extravehicular Activity	$51.7	$43.1
Shuttle Integration	$207.1	$155.3
Institutional Support	$156.9	$137.2
Construction of Facilities	$10.5	$12.3
Total Expenses	**$3,325.0**	**$2,963.1**

Safety & Supportability Upgrades included in cost.

Figure 1 provides a comparison of the budget and expenses between FY2000 and FY2001. The increases in both capital and expenditures is due to the approval of the safety upgrades for implementation.

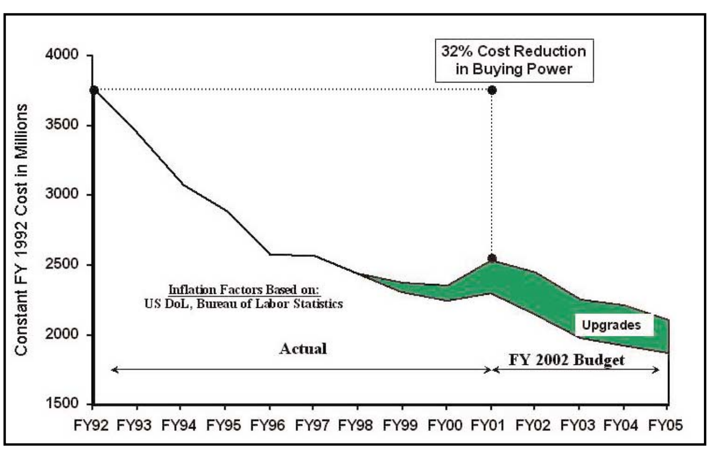
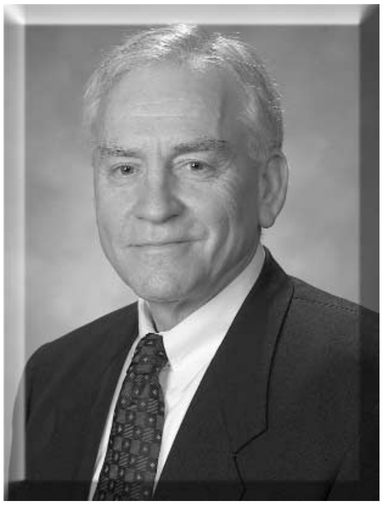


Figure 2 highlights the success achieved by the SSP reducing required operating expenses. A significant buying power reduction has been absorbed while still implementing several safety upgrades.



Elric N. McHenry, Manager,
Space Shuttle Development (JSC)

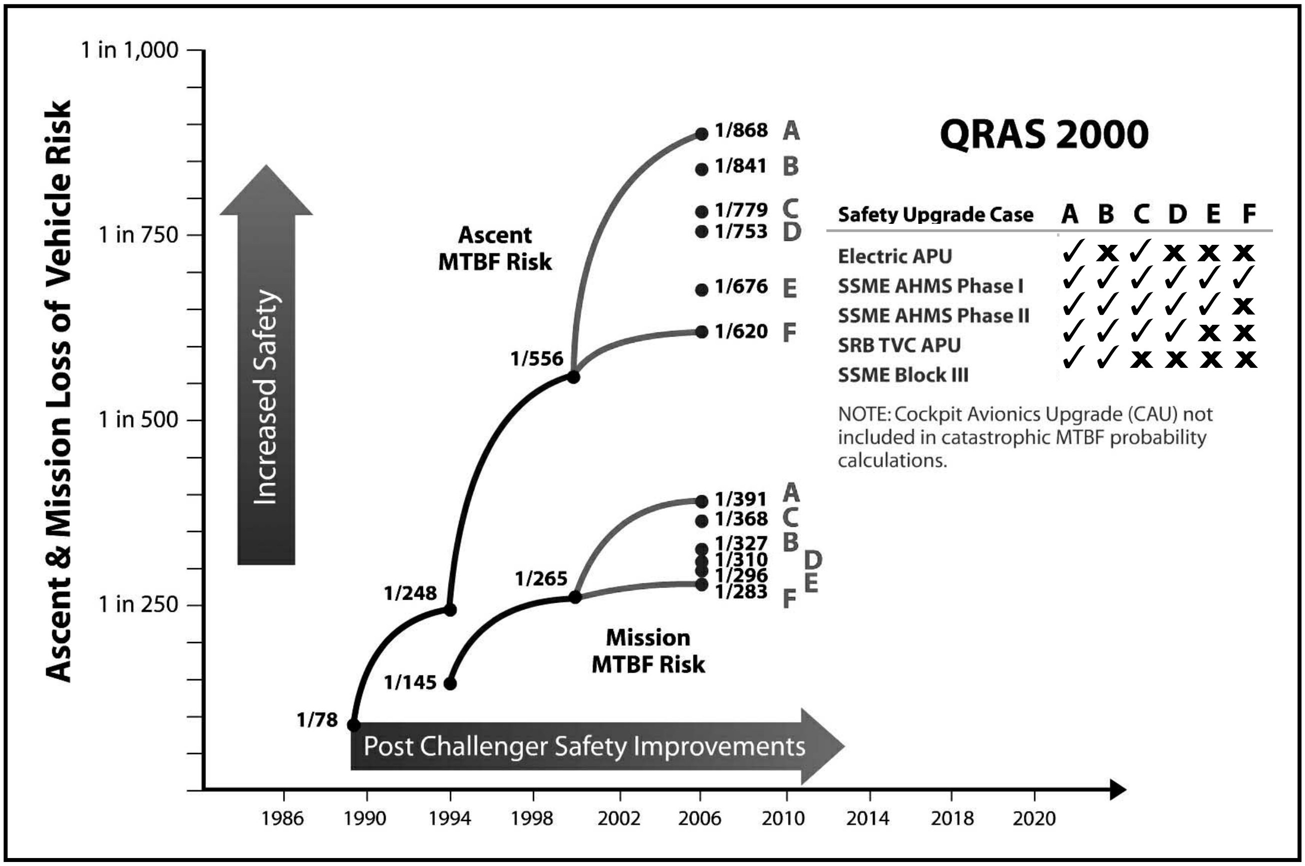
Development Milestone for Cockpit Avionics Highlights Progress on Safety Upgrades…

Excellent progress was made implementing our ambitious plans for a vigorous safety and supportability upgrade program. Significant milestones were achieved on the Cockpit Avionics Upgrade (CAU), SSME Advanced Health Management System (AHMS), External Tank Friction Stir Welding (FSW), improved Main Landing Gear Tire & Wheel, Long Life Alkaline Fuel Cell (LLAFC), and ground Checkout and Launch Control System Projects.

Development efforts on each of these will continue in 2002. Excellent progress was also accomplished in defining, analyzing, and planning the proposed electric auxiliary power unit (EAPU) and solid rocket booster (SRB) thrust vector control/auxiliary power unit (APU) upgrades. Implementation of these two projects has been deferred due to technical readiness of the EAPU and overall SSP funding priorities.

Completion of the project definition and formulation phase of the CAU Project was a major achievement. After an intensive requirements and planning effort, this project received management approval to proceed into implementation. The CAU will provide a major increase in Space Shuttle operational safety by significantly improving flight crew situational awareness, especially for abort situations, and by significantly improving flight crew operational margins in responding to time- and safety-critical system failure scenarios. Solid technical progress was also made on the extremely important SSME AHMS safety upgrade project. That project completed a Critical Design Review for Phase 1 and proceeded into system development. The AHMS project team also made excellent progress in developing system requirements, systems analysis, and a preliminary implementation plan for AHMS Phase 2, which is a proposed major extension of Phase 1 capabilities. The External Tank Friction Stir Weld Project completed the major facility modifications in the Michoud Assembly Facility (MAF) needed to accommodate the new welding tooling. The welding equipment, which completed development in 2001, will be shipped to MAF early in 2002 for installation and checkout.

Systems analysis and prioritization of proposed system safety upgrade candidates continues to be updated in support of management investment decisions. Program elements continue to support this prioritization effort and the development of analysis tools to provide relative quantification of risk reduction potential, as shown on page 15.



Safety Benefits of Space Shuttle Upgrades

Safety Upgrades

Cockpit Avionics Upgrade

The CAU will facilitate better use of the new glass cockpit. The upgrade will provide the computers, interfaces, and software that will increase the amount of information that can be displayed to the crew. These display improvements will provide added crew insight into failures, significantly reduce crew workload, increase awareness during critical flight situations, and enhance the caution and warning system for rapid problem resolution. Over the past year, the CAU project team completed a very successful formulation effort and has received authority to proceed into implementation.

Electric Auxiliary Power Unit

An EAPU was evaluated as a replacement for the existing hydrazine APU that drives the hydraulics to move the Orbiter's main engines, landing gear, and aerodynamic surfaces during flight. The primary benefit will be to replace the volatile, toxic hydrazine fuel and high-speed gas turbine with batteries and an electric motor. This change will significantly reduce risks associated with potential fuel leaks in flight and during ground handling. Major design and technology development occurred over this year; however, implementation has been delayed while further study of options to reduce the cost and weight of the system is completed.

Main Landing Gear Tire

Redesign of the Orbiter's main landing gear tire and wheel will increase the tire load capacity by 20% by adding 2 more plies to the existing 16 and by adding new belt material. This added margin will reduce the risk of a tire failure and increase the Orbiter's tolerance to cross winds while accommodating higher landing speeds. The wheel changes will compliment the tire's new load capacity. Testing of nine different tire alternatives has been completed as part of this effort.

Advanced Health Management System

This upgrade provides additional health monitoring capability for the SSME. This upgrade is planned in two phases. Phase I, which has been approved for implementation, upgrades the SSME controller and adds a real-time turbopump vibration redline system. Phase II, which is currently in formulation, adds a health management computer (HMC) to run a more advanced real-time vibration redline system and a linear engine model to identify pending failures before the failures become catastrophic. Each phase reduces the risk of a catastrophic engine failure by more than 20%.

Solid Rocket Booster (SRB) Auxiliary Power Unit Upgrade

The SRB project completed study of several replacement options for its APU used for thrust vector control during ascent. The SRB APU, like that of the Orbiter, is based on a hydrazine-powered turbine that drives the hydraulic system pump. The goal of this upgrade is to eliminate the inherent hazards associated with the toxic, flammable hydrazine-powered system. The design option selected as part of this year's effort was a pressurized helium-powered turbine that drives the hydraulic system pump. Significant design detail has been added during this year's formulation effort.

Friction Stir Welding

The FSW, a solid-state welding process for replacement of arc welding of external tank longitudinal welds, has continued development this year. FSW produces very high weld strength, near that of the parent material; results in near-zero defects; and significantly reduces manufacturing cycle times.

Supportability Upgrades

Auxiliary Information System (AIS)

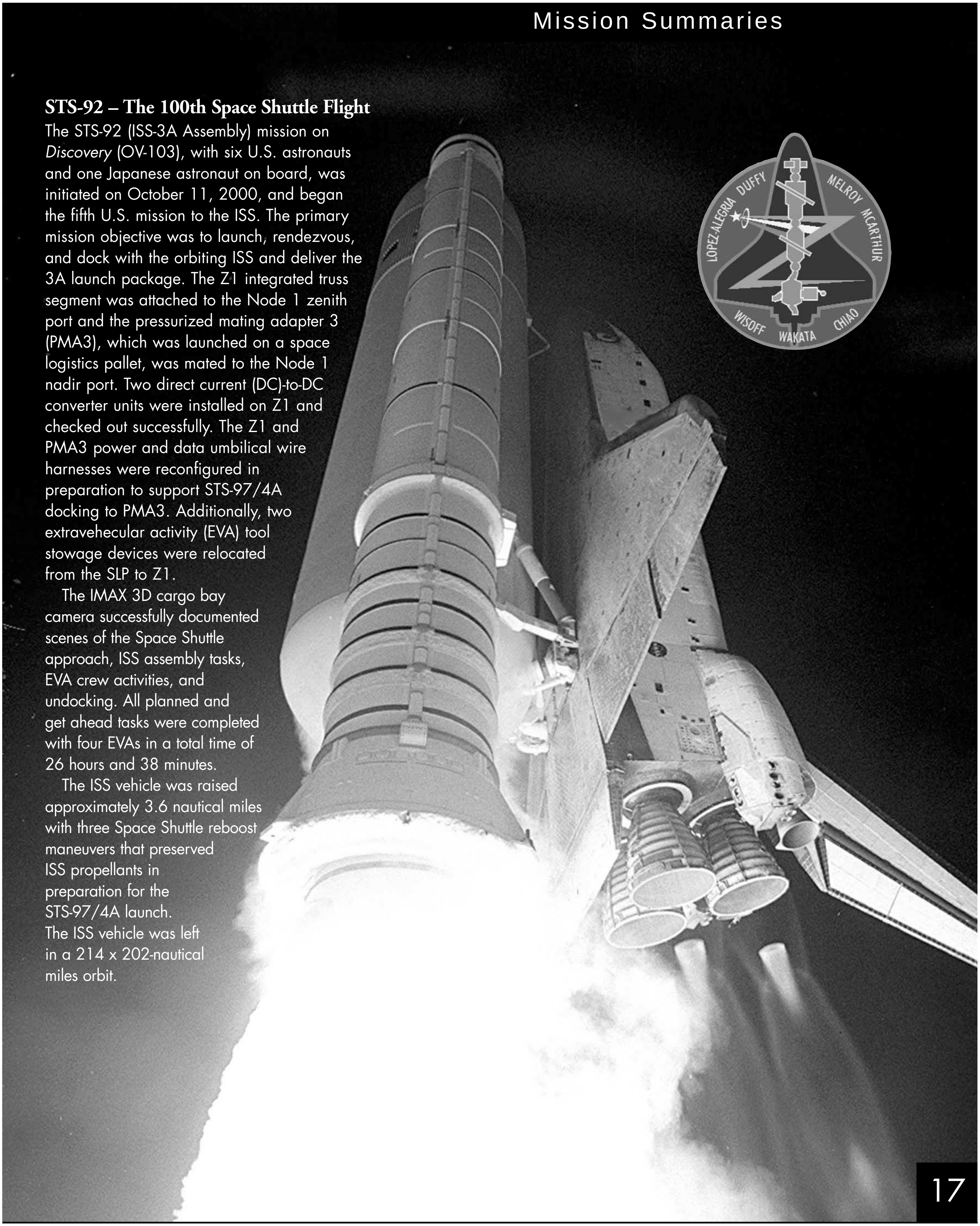
The AIS will be a digital data recorder to replace the modular auxiliary data system, an analog tape recorder. Analog tapes are no longer manufactured for this recorder, and a replacement system is needed. The AIS will record and dump a variety of valuable engineering data and high-speed main engine vibration data. The AIS is currently in the formulation phase.

Long Life Alkaline Fuel Cell

The LLAFC will double the life of fuel cells to 5,000 hours. Currently the LLAFC effort is in the implementation phase, and full-scale fuel cell stacks are undergoing long-duration testing, which has been completely successful thus far.

Supportability Upgrades Under Consideration

In addition to these supportability upgrades, the Space Shuttle Program Development office has been aggressively evaluating other supportability improvement upgrades. Supportability upgrades address flight hardware availability assurance and operational improvements. Flight hardware availability projects consider obsolescence, failure rates, repair times, and inventory attrition. Operational improvement candidates include maintainability, mission success, flight preparation, vehicle turn-around, and cost-reduction considerations. Significant supportability upgrades currently being evaluated are the Orbiter's Ku-band communication and radar system, SRB integrated electronics assembly (IEA), and the SRB automated booster assembly checkout system (ABACS). ◆

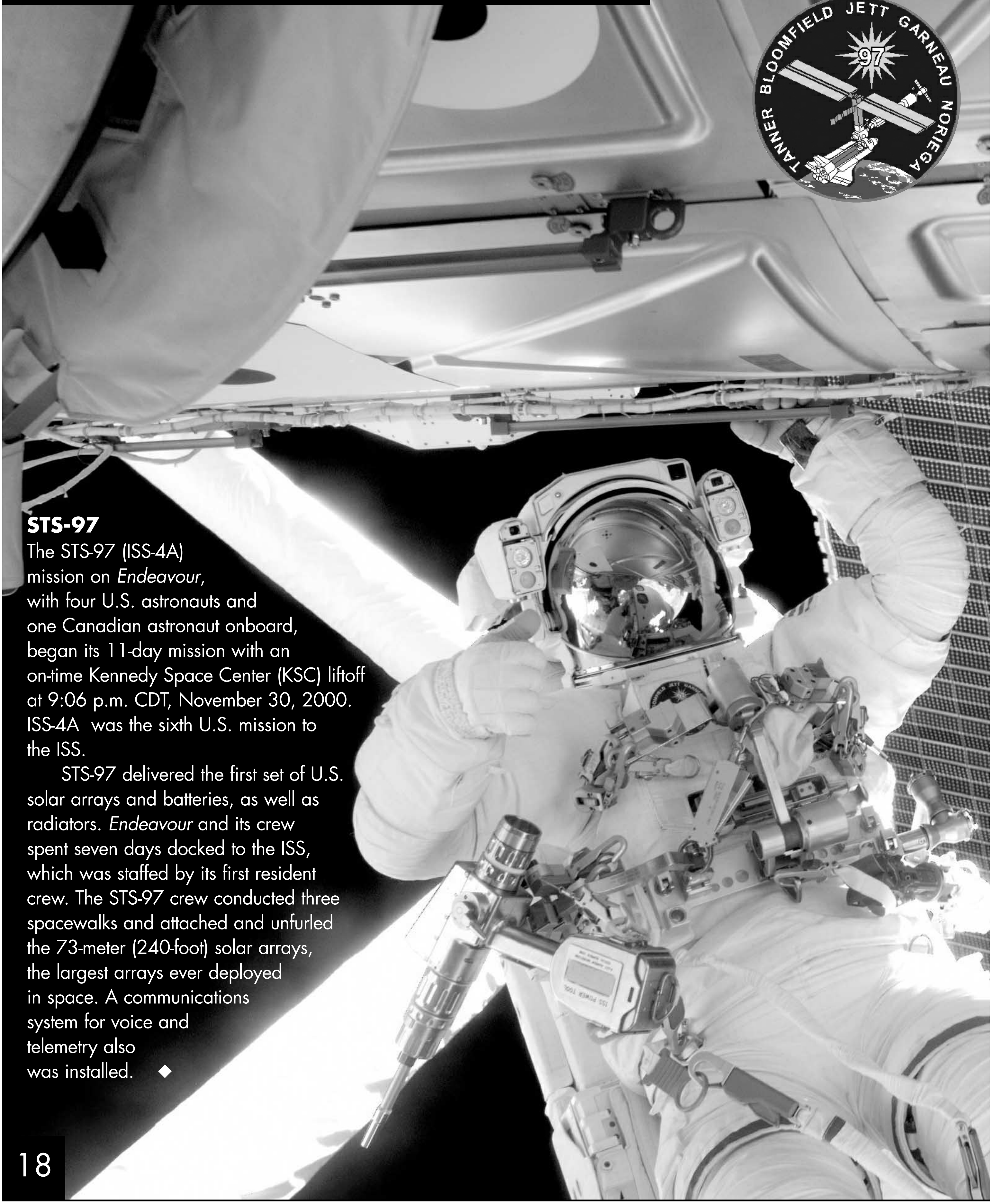


STS-92 – The 100th Space Shuttle Flight

The STS-92 (ISS-3A Assembly) mission on *Discovery* (OV-103), with six U.S. astronauts and one Japanese astronaut on board, was initiated on October 11, 2000, and began the fifth U.S. mission to the ISS. The primary mission objective was to launch, rendezvous, and dock with the orbiting ISS and deliver the 3A launch package. The Z1 integrated truss segment was attached to the Node 1 zenith port and the pressurized mating adapter 3 (PMA3), which was launched on a space logistics pallet, was mated to the Node 1 nadir port. Two direct current (DC)-to-DC converter units were installed on Z1 and checked out successfully. The Z1 and PMA3 power and data umbilical wire harnesses were reconfigured in preparation to support STS-97/4A docking to PMA3. Additionally, two extravehecular activity (EVA) tool stowage devices were relocated from the SLP to Z1.

The IMAX 3D cargo bay camera successfully documented scenes of the Space Shuttle approach, ISS assembly tasks, EVA crew activities, and undocking. All planned and get ahead tasks were completed with four EVAs in a total time of 26 hours and 38 minutes.

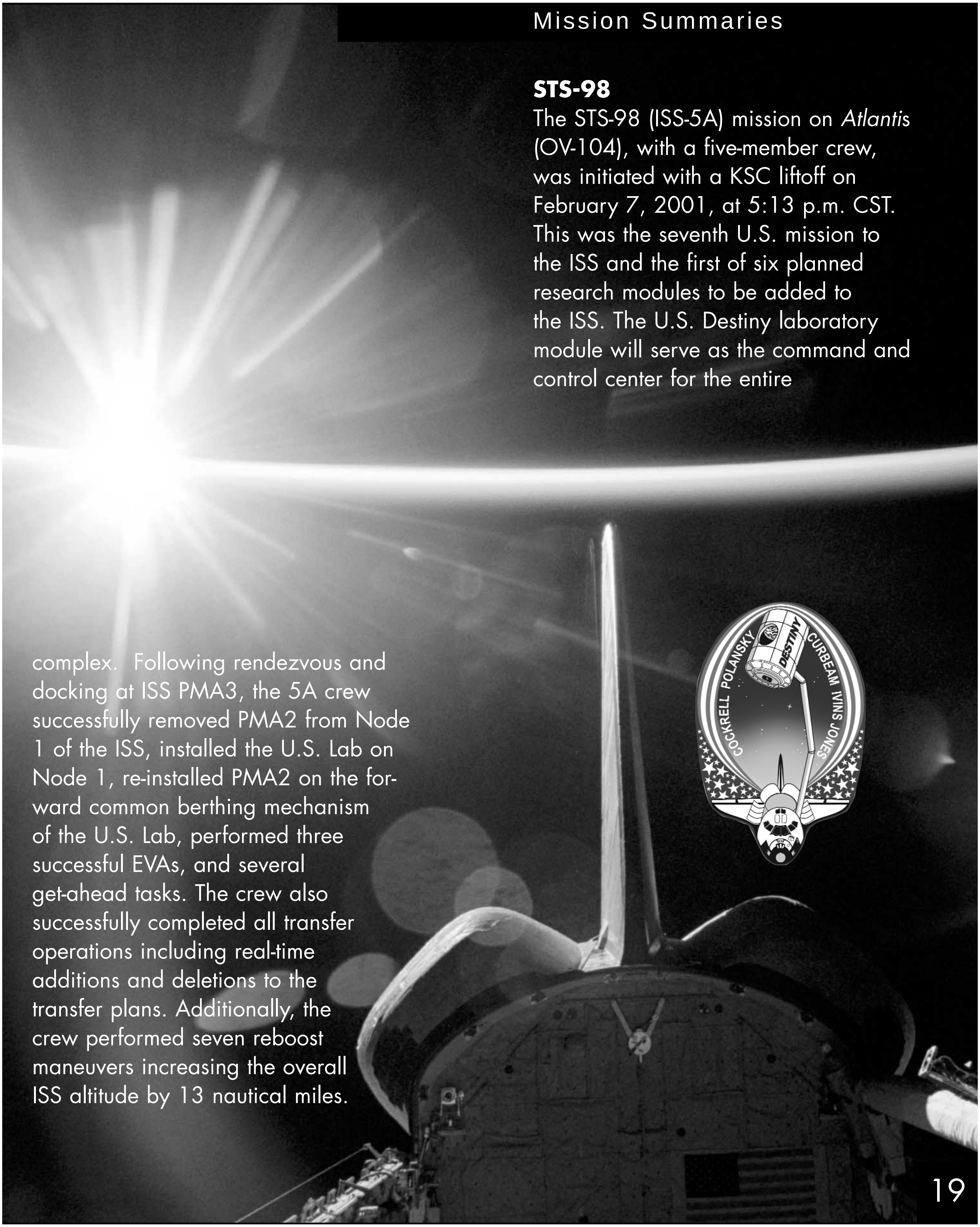
The ISS vehicle was raised approximately 3.6 nautical miles with three Space Shuttle reboost maneuvers that preserved ISS propellants in preparation for the STS-97/4A launch. The ISS vehicle was left in a 214 x 202-nautical miles orbit.



STS-97

The STS-97 (ISS-4A) mission on *Endeavour*, with four U.S. astronauts and one Canadian astronaut onboard, began its 11-day mission with an on-time Kennedy Space Center (KSC) liftoff at 9:06 p.m. CDT, November 30, 2000. ISS-4A was the sixth U.S. mission to the ISS.

STS-97 delivered the first set of U.S. solar arrays and batteries, as well as radiators. *Endeavour* and its crew spent seven days docked to the ISS, which was staffed by its first resident crew. The STS-97 crew conducted three spacewalks and attached and unfurled the 73-meter (240-foot) solar arrays, the largest arrays ever deployed in space. A communications system for voice and telemetry also was installed. ◆



STS-98

The STS-98 (ISS-5A) mission on *Atlantis* (OV-104), with a five-member crew, was initiated with a KSC liftoff on February 7, 2001, at 5:13 p.m. CST. This was the seventh U.S. mission to the ISS and the first of six planned research modules to be added to the ISS. The U.S. Destiny laboratory module will serve as the command and control center for the entire complex. Following rendezvous and docking at ISS PMA3, the 5A crew successfully removed PMA2 from Node 1 of the ISS, installed the U.S. Lab on Node 1, re-installed PMA2 on the forward common berthing mechanism of the U.S. Lab, performed three successful EVAs, and several get-ahead tasks. The crew also successfully completed all transfer operations including real-time additions and deletions to the transfer plans. Additionally, the crew performed seven reboost maneuvers increasing the overall ISS altitude by 13 nautical miles.

STS-102

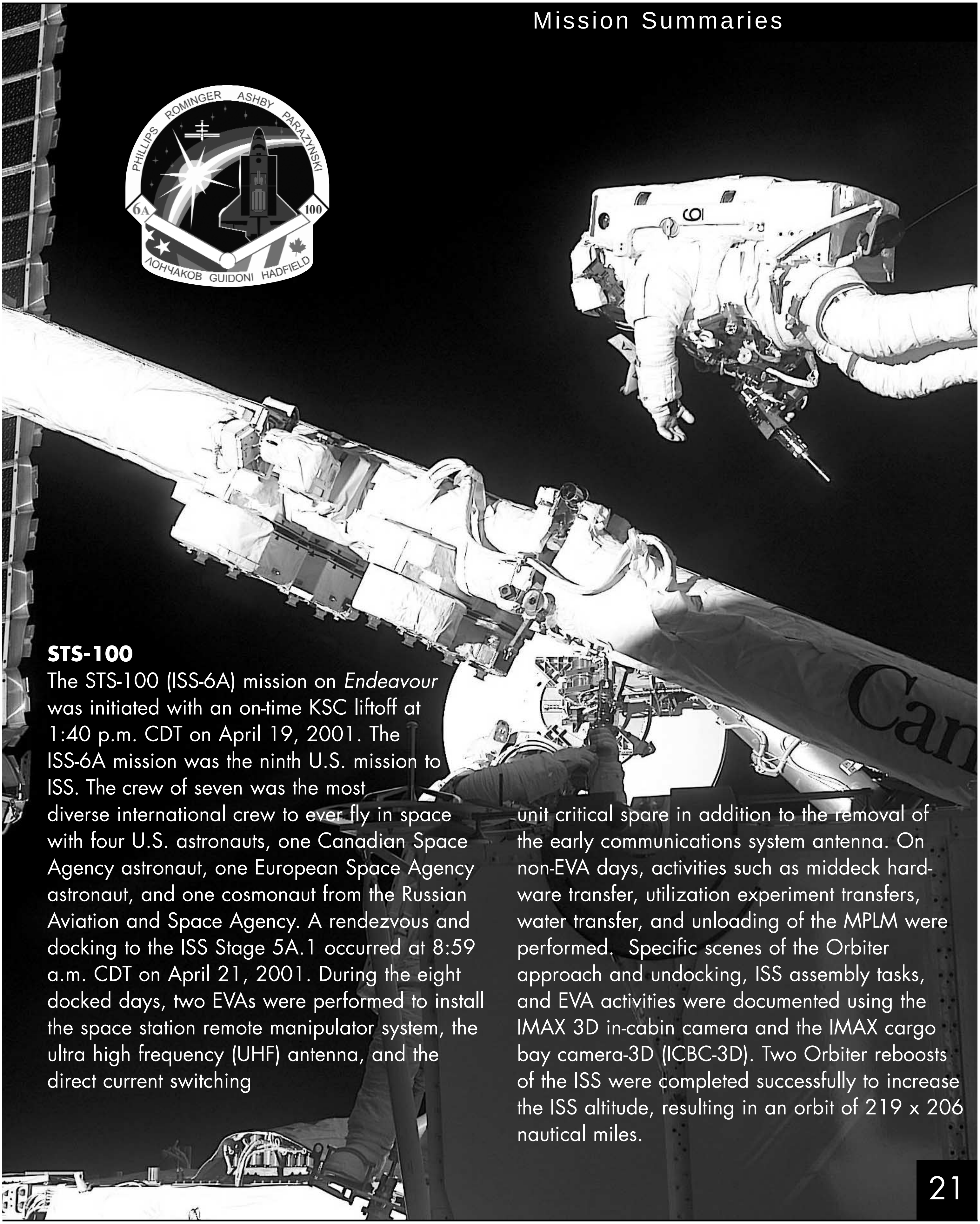
The STS-102 (ISS-5A.1) 13-day mission on *Atlantis* was initiated with an on-time KSC liftoff on March 8, 2001, at 5:42 a.m. CST, and began the eighth U.S. mission to the ISS. The crew consisted of seven going up and seven coming down, completing the first ISS crew rotation of three crewmembers. Two spacewalks were successfully performed, consisting of scheduled and additional tasks. This mission was the first flight of the Leonardo multi purpose logistics module (MPLM), and the fourth flight of the integrated cargo carrier, used for the mounting of external transfer items.

Once the rendezvous and docking with the ISS was completed, the first EVA was performed which included tasks that would enable the relocation of PMA3 from the Node 1 nadir location to the Node 1 port location via the remote manipulator system (RMS). Berthing of the MPLM at the Node 1 Nadir location was then completed using the RMS.

In addition to the ISS activities, there were three payloads in the cargo bay: wide-band Shuttle vibration forces measurement (WSVFM), get-away special-783 (GAS-783), and space experiment module (SEM-09).

The WSVFM, managed by the Jet Propulsion Laboratory, obtained flight measurements of the vibration forces acting between a payload and its mounting structure, including acceleration data at high and low frequencies.

Both the GAS-783 and the SEM-9 are managed by the Goddard Space Flight Center (GSFC). GAS-783 contained 47 experiments provided by schools in the St. Louis, Missouri, area, which were completely passive and self-contained within a standard-sealed 2.5- cubic-foot GAS canister. The SEM-9 experiment used a GAS canister, divided into 10 modules, to accommodate small zero- or micro- gravity experiments. The primary science objective was the quantification of extraterrestrial particles and other orbital debris present in the Orbiter bay. This "passive" sponge collected microscopic debris on-orbit and retained this debris for postflight evaluation by students ranging from kindergarten through university.

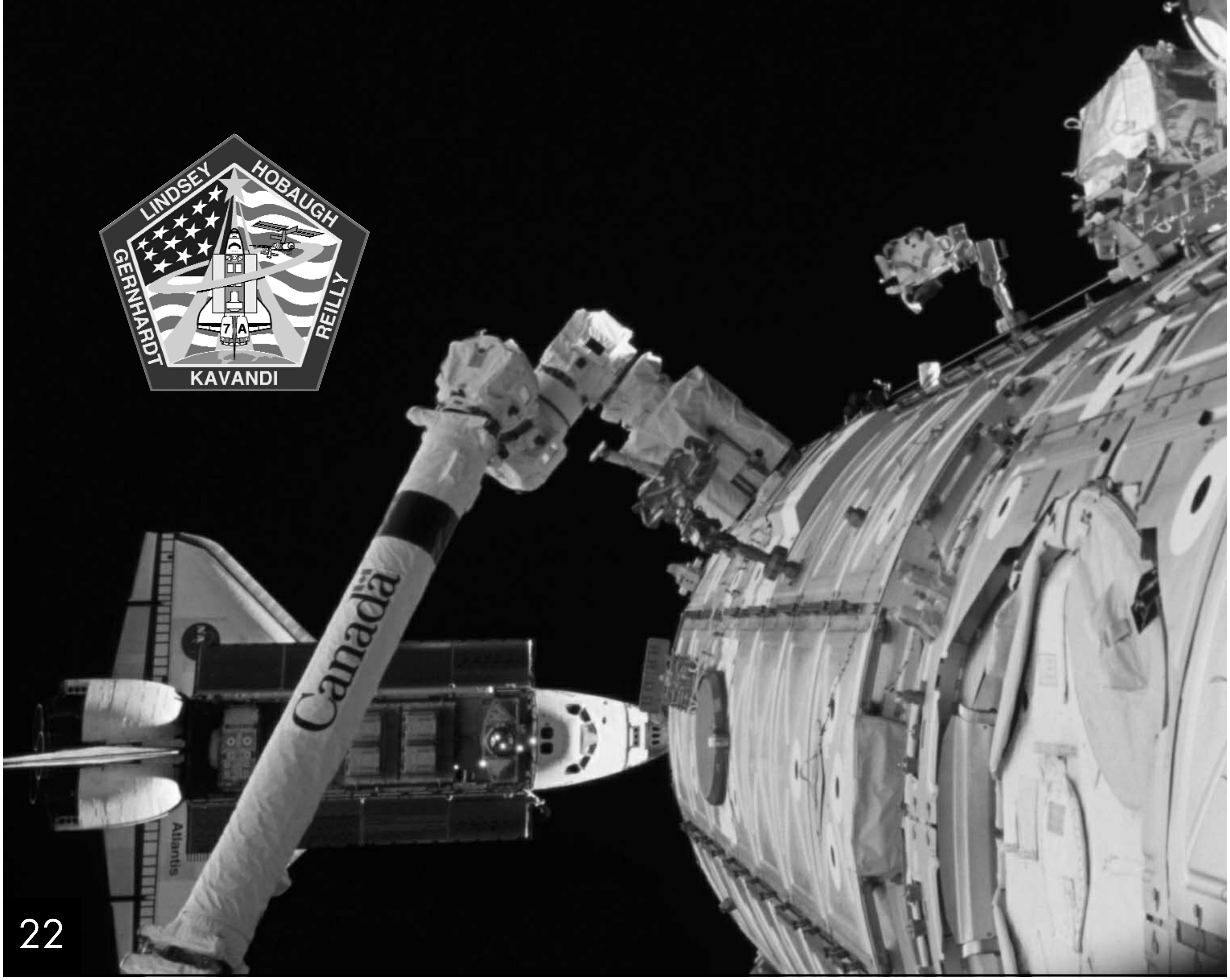


STS-100

The STS-100 (ISS-6A) mission on *Endeavour* was initiated with an on-time KSC liftoff at 1:40 p.m. CDT on April 19, 2001. The ISS-6A mission was the ninth U.S. mission to ISS. The crew of seven was the most diverse international crew to ever fly in space with four U.S. astronauts, one Canadian Space Agency astronaut, one European Space Agency astronaut, and one cosmonaut from the Russian Aviation and Space Agency. A rendezvous and docking to the ISS Stage 5A.1 occurred at 8:59 a.m. CDT on April 21, 2001. During the eight docked days, two EVAs were performed to install the space station remote manipulator system, the ultra high frequency (UHF) antenna, and the direct current switching unit critical spare in addition to the removal of the early communications system antenna. On non-EVA days, activities such as middeck hardware transfer, utilization experiment transfers, water transfer, and unloading of the MPLM were performed. Specific scenes of the Orbiter approach and undocking, ISS assembly tasks, and EVA activities were documented using the IMAX 3D in-cabin camera and the IMAX cargo bay camera-3D (ICBC-3D). Two Orbiter reboosts of the ISS were completed successfully to increase the ISS altitude, resulting in an orbit of 219 x 206 nautical miles.

STS-104

The STS-104 (ISS-7A) mission on *Atlantis* successfully launched on time from KSC on July 12, 2001. The ISS-7A mission was the tenth U.S. mission to the ISS, and consisted of a five-member crew. A successful rendezvous and docking to the ISS Stage 6A occurred at 10:05 p.m. CDT on July 13, 2001. During the eight docked days, three EVAs were performed to install the joint airlock and four high pressure gas tanks. Eight EVA get-ahead tasks were also performed. Inside the orbiting vehicles, airlock activation and checkout, middeck hardware transfer, utilization experiment transfers, and water transfer, were performed. Specific scenes of the Orbiter approach and undocking, ISS assembly tasks, and EVA activities were documented using the IMAX-3D in-cabin camera, and the IMAX ICBC-3D. Three Orbiter reboost periods of the ISS were completed, successfully increasing the ISS altitude 8 nautical miles .



STS-105

The STS-105 (ISS-7A.1) mission on *Discovery* was initiated with an on-time KSC liftoff at 4:10 p.m. CDT on August 10, 2001. The ISS-7A.1 mission was the eleventh U.S. mission to the ISS, and consisted of a seven-member crew (three ISS crewmember rotation). After docking, the MPLM, Leonardo, was successfully un-berthed and installed on Node 1 of the ISS. During the eight docked days, the Expedition 3 crew handover and two EVAs were performed, and all transfers between the Shuttle middeck, MPLM, and ISS were completed. Two ISS reboosts were also performed, increasing the ISS altitude from 212 to 219 nautical miles.

During the docked time, seven new payloads were transferred from the Space Shuttle to the ISS to support Increment 3 activities, and six payloads and numerous data were transferred back from the ISS to the Space Shuttle for return and scientific evaluation. Among the payloads transferred to the ISS was the first commercial payload, DREAMTiME, a high definition television camcorder that captured a number of activities on both the Space Shuttle and the ISS. Also transferred were the first external payloads: two materials International Space Station experiments (two MISSEs), which were transferred and deployed during the first EVA. In addition to the MISSEs, the first EVA also transferred the early ammonia servicer. The second EVA transferred and installed launch-to-activation cables for the S0 truss element as a get-ahead task for the 8A mission. Both EVAs were successfully completed during the mission.

In addition to the ISS activities, the cargo bay contained several GSFC managed payloads. These included the Hitchhiker Experiments Advancing Technology (HEAT) and a GAS payload, G-780.

HEAT was comprised of the SimpleSat ejectable satellite, the advanced carrier equipment (ACE) avionics system, GAS payload 774 (G-774) and the SEM. SimpleSat was an engineering test satellite designed to evaluate the use of inexpensive commercial hardware on spacecraft. After the Space Shuttle undocked from the ISS, the crew executed a flawless deploy of the SimpleSat satellite. SimpleSat will orbit the Earth for about 5 months before atmospheric drag will cause it to re-enter.

The ACE was designed as an enhancement of and eventual replacement for the existing Hitchhiker (HH) avionics as the power and data interface to the Orbiter electronics for HH payloads. ACE provides the same services and electrical interfaces as the HH avionics, but with enhancements and system redundancy. STS-105 marks the first flight of the ACE assembly. Over the course of the 12-day flight, ACE met its mission success objectives.

The STS-105 crew successfully commanded the operations of the G-774 and G-780 payloads on orbit. G-774 was a GAS experiment that had the objective of validating the model for theoretical predictions of smolder propagation to enhance our understanding of the smolder hazard. G-780 was a GAS experiment that investigated cell growth in micro-gravity and was sponsored by the Mayo High School in Rochester, Minnesota.

The SEM canister was comprised of 10 small-enclosed modules, each containing several passive experiments designed and constructed by students.

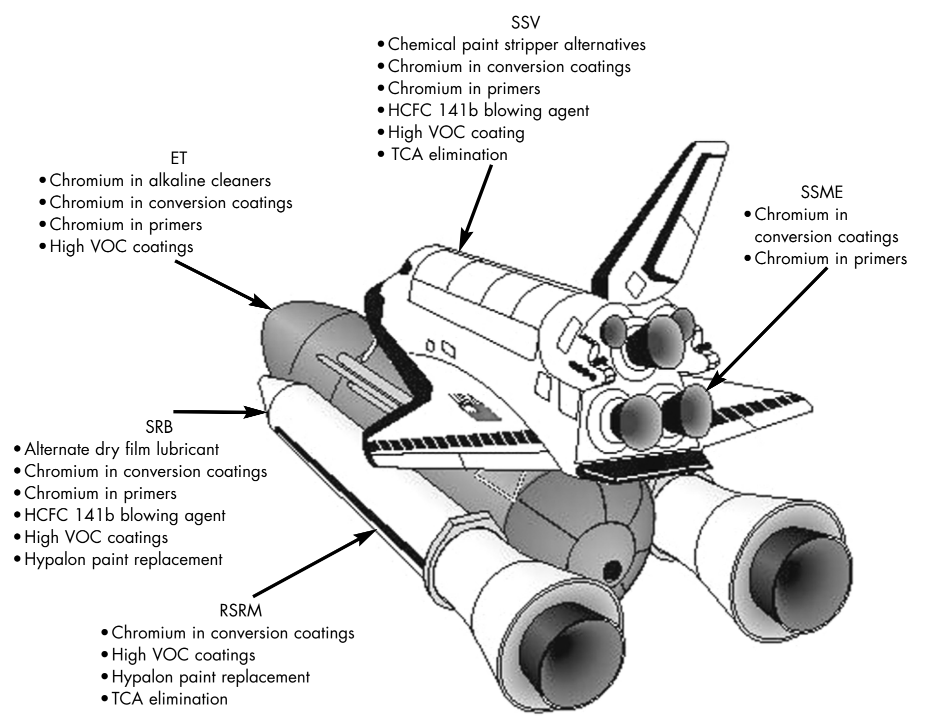
Jolene J. Martin, Manager,
Shuttle Integration Office (MSFC)

SEA Promotes Cooperative Effort to Achieve Environmental Excellence…

…and proactively manage materials obsolescence. Interfaces with groups within NASA, including the NASA Materials Replacement Technology Team, the Headquarters and Centers' Environmental Management Offices, and the Acquisition Pollution Prevention Office, along with other government agencies and private industry have been developed to leverage resources and enhance technology transfer opportunities.

The increasing promulgation of international, federal, state, and local environmental regulations is affecting all aspects of aerospace manufacturing operations. The Shuttle Environmental Assurance (SEA) Initiative assures that regulations are identified, reviewed for impact, and reported through the appropriate channels.

Potential issues are analyzed and categorized in accordance with the Issue and Continuous Risk Management process. Issues currently in work by the SEA Initiative are highlighted at right. ◆

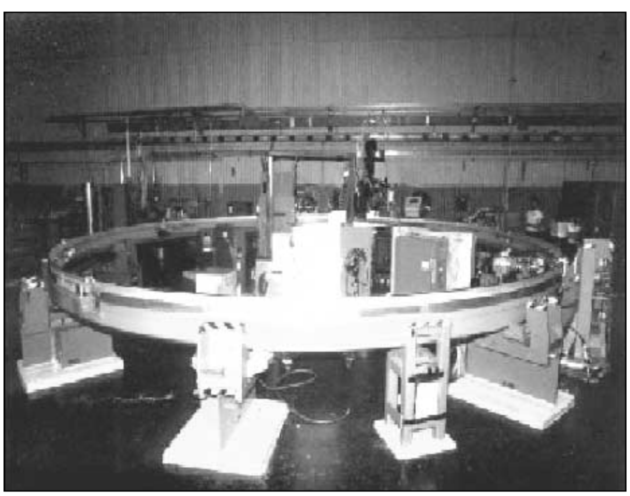


Open SEA Initiative Issues

Jerry W. Smelser, Manager, External Tank (MSFC)

External Tank Implements State-of-the-Art Digital X-ray…

…which will improve processing time and increase flaw detection capability. The liquid hydrogen tank, the liquid oxygen tank, and the intertank, which joins the two pressure vessels, consist of over 36,000 inches of welded joints. The previous method of weld joint verification, film radiography, was time consuming, difficult to interpret, required environmental disposition of film-processing chemicals, and needed significant storage volume to maintain processed X-ray film. Digital X-ray images can be produced in a fraction of the time, are much easier to interpret, are environmentally friendly, and can be stored on a computer disk.



T-Ring Weld and X-ray Tool

The T-ring weld and X-ray tool, a fairly simple application, was chosen for first implementation to prove the concepts and to develop operator capability. The second application, the dome digital X-ray tool, is scheduled for implementation in December. Thus far, expectations have been met or exceeded in every respect. The digital radiography system is reducing production cycle time and producing superior results for weld quality verification.

Dome Digital X-ray Tool

Lean Manufacturing/Statistical Process Control

An aggressive lean manufacturing/statistical process control plan is under way and showing improvements in quality and cost metrics. Targeted worksites undergo a week-long Kaizen Events analysis to optimize workspace and workflow. Statistical process control is employed as a follow-up to systematically refine and reduce process variability. As part of this effort, metrics are developed to evaluate long-term success.

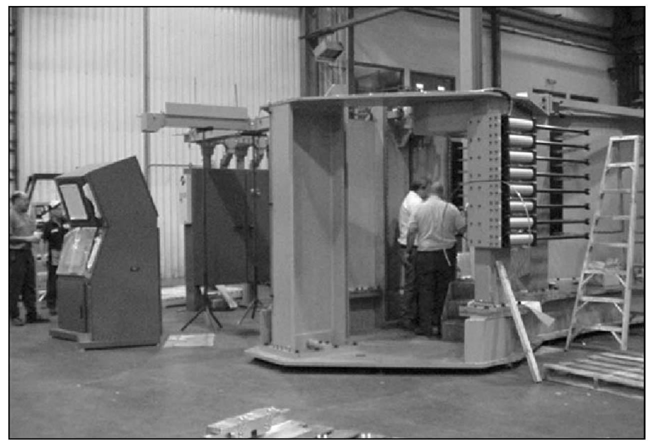
Performance measurements on converted worksites confirm improvements in quality, cost, required manufacturing floor space, and part/employee travel distance.

Initial Workspace / Workflow

Improved Workspace / Workflow

External Tank (ET) Friction Stir Weld (FSW) Safety Upgrade

Training hardware, facility modifications, and initial production tooling have all been completed in support of the July 2002 implementation of friction stir welding (FSW) in the ET production line. FSW, which will be used on the liquid oxygen and liquid hydrogen barrel section longitudinal welds, will provide increased safety margin and reduce manufacturing cost and schedule.

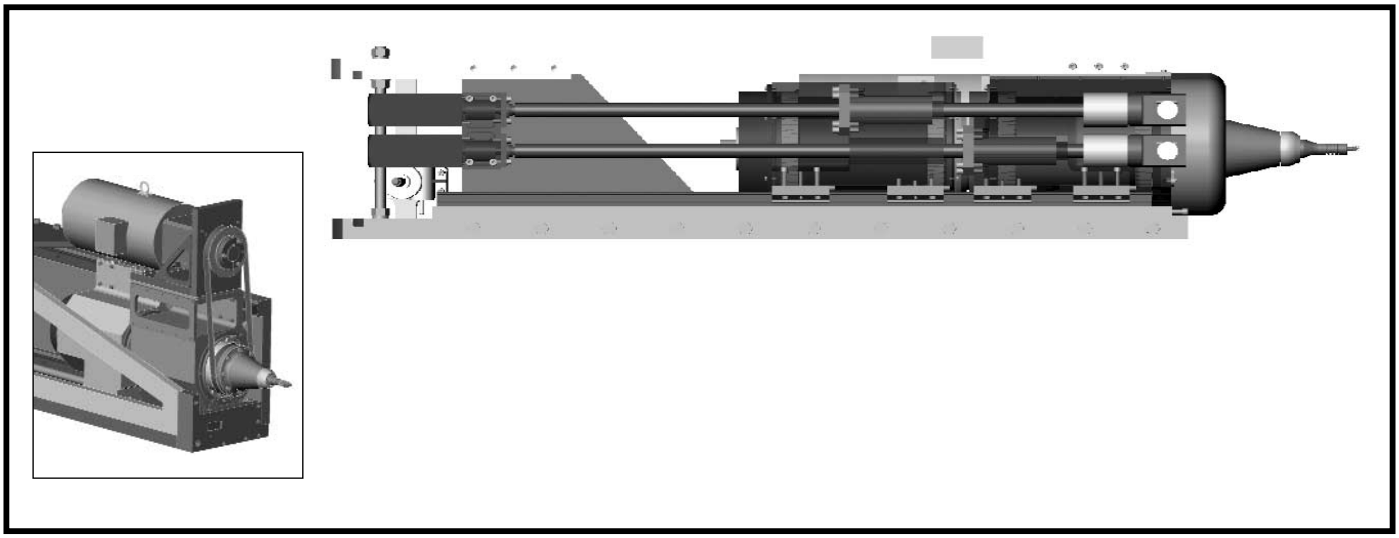


FSW Trainer Tool

The FSW trainer tool, a 1/4-scale replication of the production tool, was delivered to the Michoud Assembly Facility (MAF) in October.

The MAF modifications, which included construction of a 90-foot long, 50-foot wide, and 15-foot deep pit to house the production tooling, was completed on time without interference with the ongoing ET manufacturing.

FSW Facility



Retractable Pin FSW Tool

Several risk-mitigation steps have been implemented on this project to ensure successful implementation. One of the more notable items surfaced by the risk mitigation plan was the potential for a lack-of-penetration in the tapered barrel sections. This risk has been mitigated by the addition of a retractable pin FSW tool that includes laser sensors to allow real-time compensation for thickness variations that occur in the tapered welds.

All elements of the FSW Project are on schedule to support implementation in July 2002 and will be a major enhancement to the producibility and safety of the Space Shuttle's ET.

PMES Workstation

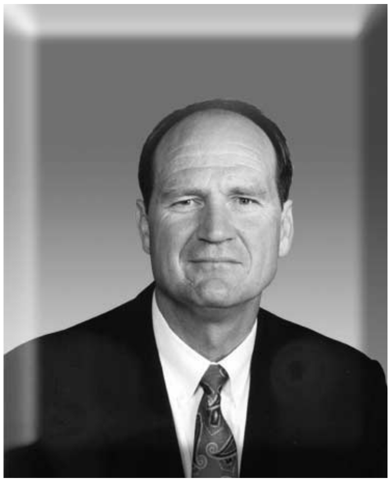
External Tank Paperless Manufacturing Execution System

In fiscal year (FY) 2003, all work orders and supporting documentation required to assemble an ET will be generated and processed electronically. This new system will provide improvements in work instruction and non-conformance documentation quality, process control, and operational efficiency.

To prepare for this transition, and to substantiate the benefits prior to implementation, a Paperless Manufacturing Pilot Center was established. Teams of operators and engineers spent several months reviewing the capabilities and limitations of various products. Following this demonstration in FY2001, the project was approved for implementation.

Concurrent with the implementation of this new capability, a fiber-optic network is being installed to support the increased capacity requirements of the paperless system.

Following implementation in FY2003, ET manufacturing will see improved efficiency, reliability, and productivity. ◆



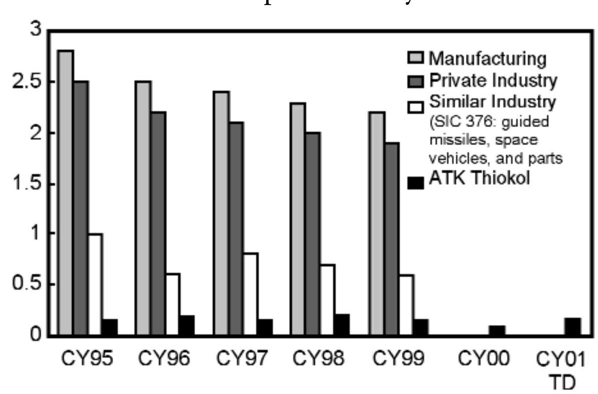
Michael U. Rudolphi, Manager,
Reusable Solid Rocket Motor (MSFC)

Ensuring On-Time Delivery and On-Target Performance…

…is a continual focus for the Reusable Solid Rocket Motor (RSRM) Project. For the eleventh consecutive year, all motor segments were delivered on schedule. All flown RSRMs performed as designed. Postflight disassembly and inspections during fiscal year (FY) 2001 revealed no significant anomalies.

FY2001 Safety Performance

Safety continues to be the principal focus in the manufacture of the Space Shuttle Program's RSRM. This is reflected in the job-related accident frequency rates at ATK Thiokol Propulsion, which have been well below the rates for similar industries, as published by the Bureau of Labor Statistics. In fact, the company's record in contract year 2000 for OSHA recordable and lost workday injury rates was at record lows for the past several years.



Lost Workday Case Incidence Rate

ATK Thiokol reached a number of significant safety milestones this past year:

- ❖ The Test Area surpassed 4.3 million hours, or 12.5 years, without a lost-time accident.
- ❖ The Nozzle Work Center surpassed 2.1 million hours, or 6.7 years, without a lost-time accident.

RSRM Independent Assessment

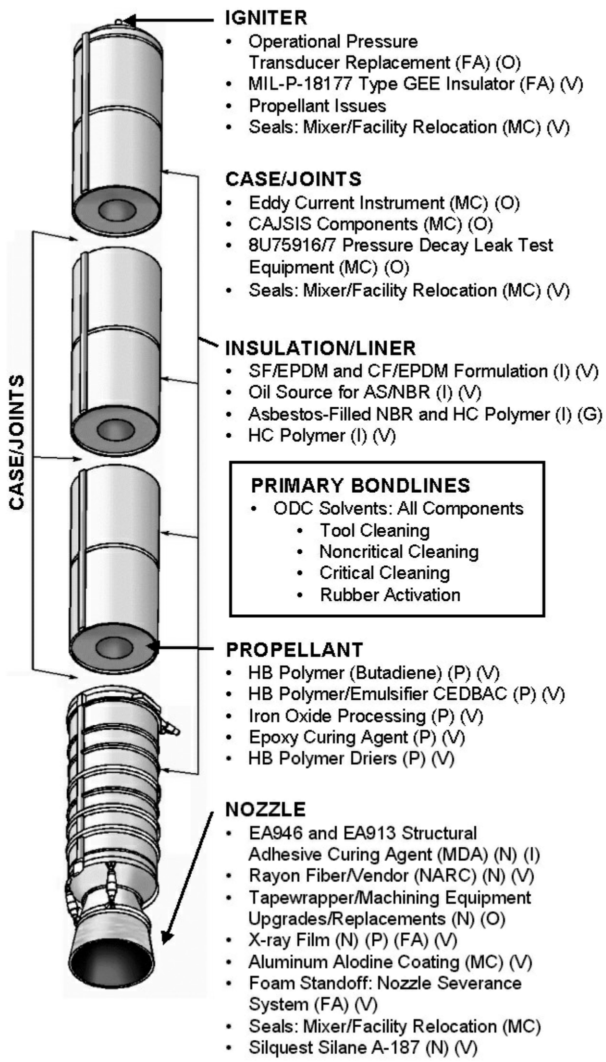
The Space Shuttle Program Office chartered an independent team to assess RSRM operations relative to a broad spectrum of program issues. The team, using independent retired NASA and corporate members, conducted their review at ATK Thiokol on March 4-9, 2001. Focus areas of the audit included:

- ❖ Facilities, equipment, and tooling
- ❖ Nondestructive evaluation (NDE) processes
- ❖ Material receiving inspection practices

The final report issued on April 11, 2001, concluded:

- ❖ The RSRM is meeting all performance requirements.
- ❖ The ATK Thiokol workforce is attuned to the criticality of process control to RSRM safety.
- ❖ Facilities, tooling, and equipment are in good condition and are being maintained in an effective manner.

- Inspection and NDE tooling and equipment are meeting existing requirements and are maintained in good operating condition.
- Materials receiving inspection is thorough and geared to detecting inferior products. However, these vendor products represent a risk to the RSRM program that requires careful management.



Responsible	Reason for Obsolescence
MC = Metal Components	G = Government Regulation (EPA, OSHA, etc.)
I = Insulation	V = Vendor Economics
P = Propellant	I = Industrial/Safety Hazard
N = Nozzle	N = Natural Disaster
FA = Fleet Assembly	O = Obsolescent Technology

RSRM Obsolescence Threats

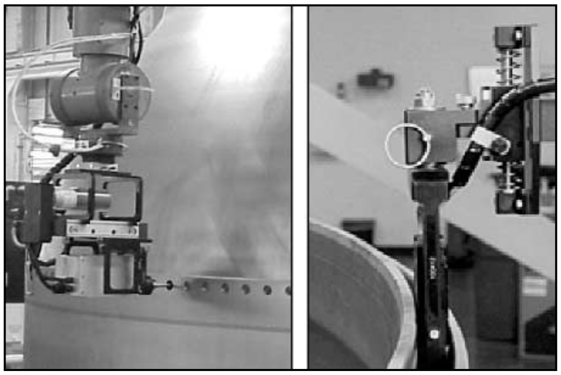
RSRM Obsolescence Mitigation

The RSRM is unique; it is comprised of diverse categories of uncommon processes, materials, and components that face the constant challenges presented by obsolescence issues that have the potential to adversely affect the RSRM. Continuous surveillance is required to anticipate and implement the necessary replacement technologies to manufacture and deliver the RSRM with unaltered configuration and performance characteristics. The figure on the left shows many of the obsolescence challenges currently facing the RSRM Project.

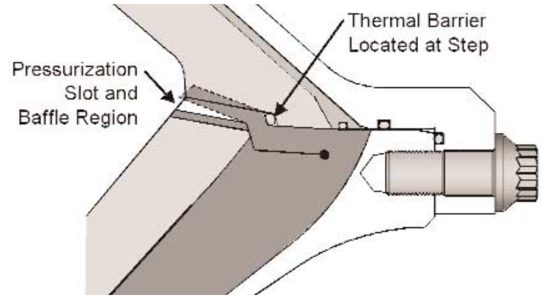
Automated Eddy Current Inspection Systems for RSRM Refurbishment

During refurbishment after flight, all RSRM hardware is cleaned to bare metal and subjected to numerous inspections: visual, dimensional, and non-destructive evaluation (proof test, magnetic particle, dye penetrant, eddy current, ultrasonic shearwave, etc.). Magnetic particle and dye penetrant inspections are visually-based; i.e., they rely on the human eye as the sensor to detect indications. Although these visual-based inspections are supported by extensive probability-of-detection studies and history, new electronic sensor-based inspections offer advantages. The RSRM Project will replace these visual-based inspections with sensor-based inspections to improve the reliability, control, and data storage of NDEs. Using sensors also allows automation of the inspection. Other benefits include inspector variability and subjectivity elimination, digital evaluation of indications, ability to calibrate, data archiving, reduced cycle time, and reduction of waste streams.

Delivery and installation occurred in early 2001, with testing successfully conducted on full-scale hardware, including flight support motor no. 10 (FSM-10). Following the successful completion of qualification testing, implementation of the new systems as a replacement for some of the current inspections is planned to begin in early 2002.



Inspection Process



Nozzle-to-Case Joint J-leg Configuration

Digital X-ray Inspection for RSRM Components

An effort is under way to develop and demonstrate state-of-the-art digital X-ray systems that will eventually replace the current wet-film technology. This new inspection technique, which actually uses the same X-ray energy source as the current system, will be used to provide the NDE of phenolic nozzle components as well as loaded and insulated motor segments.

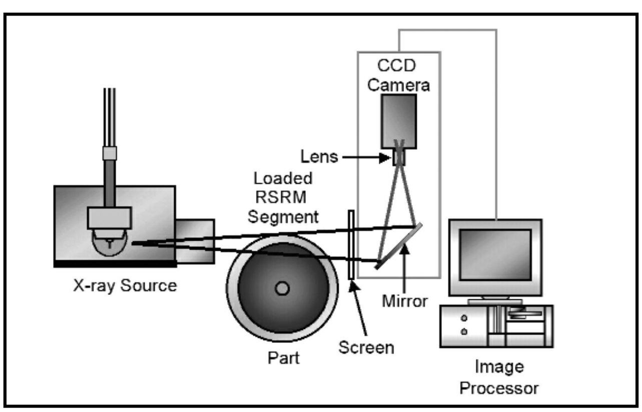
The digital image can be evaluated, enhanced, and stored as a digital file for future reference. The new digital system provides better image quality as well as improved image manipulation and enhancement capabilities. The digital data will allow for near-instantaneous retrieval of all images, making anomaly investigations and other data review activities more efficient.

Nozzle-to-Case Joint J-leg Configuration

The current RSRM nozzle-to-case joint employs a polysulfide mastic adhesive bondline as a thermal barrier in an effort to preclude gas penetration to the O-ring sealing system. In an effort to reduce or eliminate the occurrence of gas paths through the polysulfide, a design change eliminating the polysulfide and incorporating a J-leg with a carbon rope thermal barrier is being tested.

The RSRM nozzle-to-case J-leg incorporates a pressure actuated flap (J-leg) insulation design that, when deflected, is placed in circumferential tension. An enhancement for the J-leg configuration is the installation of a carbon rope thermal barrier located at the step region of the joint. In the event of gas leakage beyond the J-leg region, the thermal barrier will cool and spread any gas, thus eliminating potential heat effects on the outboard leak check barrier.

FY2001 accomplishments include the firing of FSM-9, the first full-scale static test with the improved J-leg configuration. The joint performed its intended function by keeping hot gas away from the joint seals. No hot gas penetration past the J-leg or the carbon rope thermal barrier was observed. The next full-scale static test, FSM-10, will include a channel through the J-leg to the thermal barrier. The FSM-10 firing is scheduled for August 2002.



Digital Radiography CCD System

Flight Support Motor No. 9

Full-scale RSRM static test motors are periodically tested to confirm the performance and safety of RSRM systems and certify design, component, material, and process changes. FSM-9 was successfully static tested on May 24, 2001. Extensive instrumentation (576 channels) gathered data in support of the 103 test objectives. While data evaluation continues, the FSM-9 test was a complete success. ◆

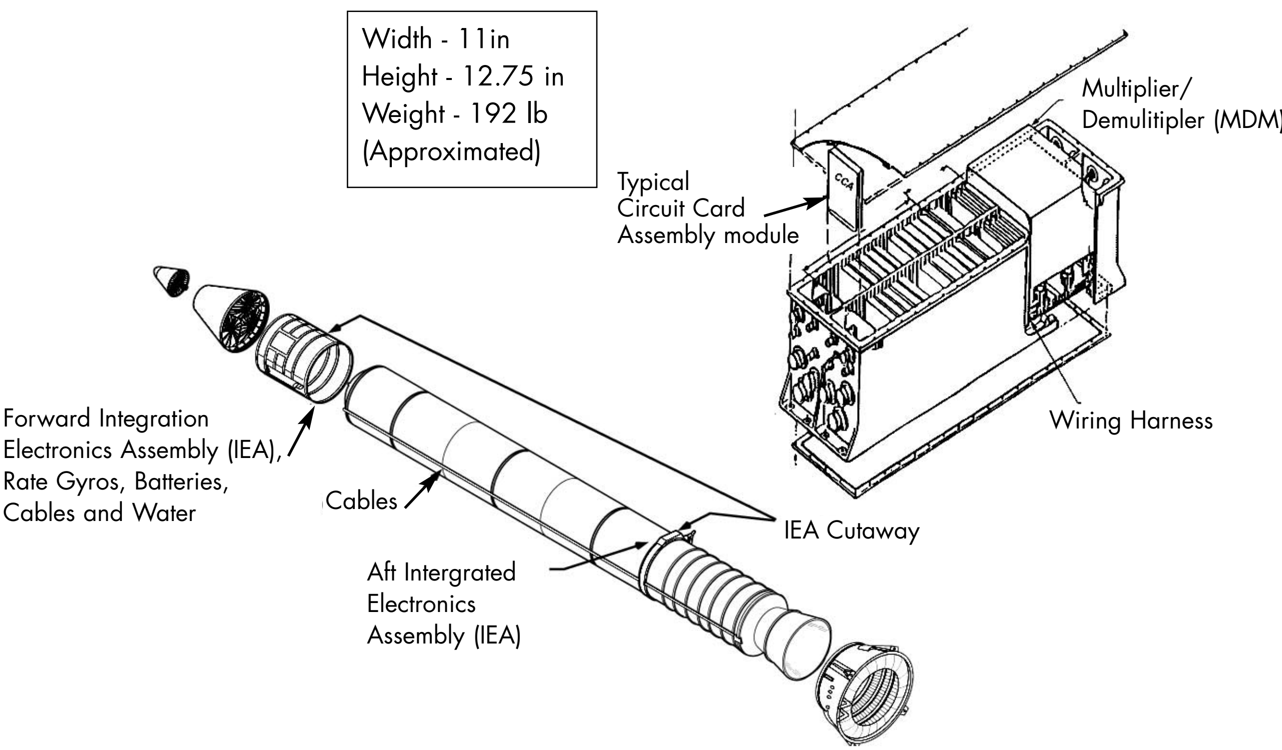
SRB Reviews, Improvements Ensure Strong Future…

Parker V. Counts, Manager,
Solid Rocket Booster (MSFC)

The Solid Rocket Booster (SRB) project office sponsored an independent assessment team to review the Space Shuttle's integrated electronics assembly (IEA) supportability posture due to concerns over aging electronics. The thoroughness of the IEA independent assessment team (ISAT) has been recognized across the program, and it has been used by other project elements to identify potential supportability issues.

The IEA, designed in the late 1970's for a 10-year life, has been an extraordinarily reliable component. However, data analysis conducted by the ISAT shows an increasing maintenance trend that projects a flight manifest impact by the year 2007 unless action is taken.

The ISAT recommendations to allow hardware supportability to the year 2020 include the manufacture of additional IEA harnesses, delta-qualification tests to extend the hardware certification life, manufacture of additional circuit card assemblies, electronic piece part procurements, and an enhancement of the problem-reporting database to provide better reliability and trending data.



SRB Advanced Thrust Vector Control (TVC) Completes Formulation, Ready for Implementation

The TVC upgrade, one of the major safety upgrades being considered by the Space Shuttle Program (SSP), has completed the formulation phase and is now ready for implementation. The proposed new TVC system, designed to reduce the chance of a catastrophic failure, uses gaseous helium to spin a turbine. The turbine provides hydraulic power to gimbal the reusable solid rocket motor nozzles to steer the Space Shuttle vehicle during flight. The current system is powered by hydrazine.

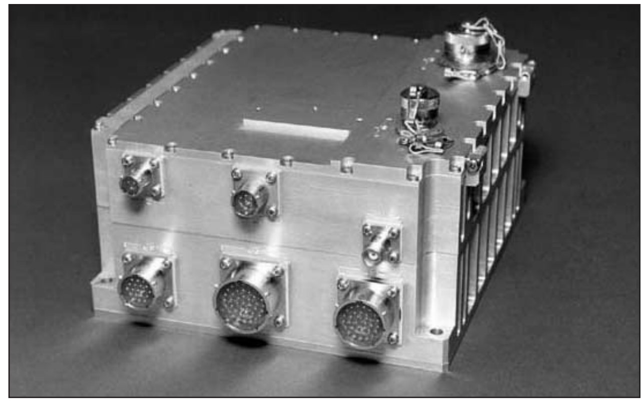
Technology demonstration testing was conducted on numerous viable concepts to determine the optimum candidate. Those evaluated included an electric motor powered by thermal batteries, a direct hydraulic pressurization concept, a solid propellant gas generator, and the helium-powered turbine.

Subsequent to the demonstration testing, a comprehensive trade study was performed prior to the selection of the helium-powered auxiliary power unit, (HeAPU), as the optimum replacement. It was chosen because it could achieve the desired safety enhancement for the lowest cost, schedule and risk. The HeAPU will increase flight safety by approximately 9.5%.

Detailed programmatic reviews were successfully completed to baseline all requirements and project planning documentation. Cost and schedule estimates were developed based on the information obtained during the formulation phase. In addition, modeling and early development testing were conducted to identify and mitigate performance risks.

SRB's New Command Receiver Decoder

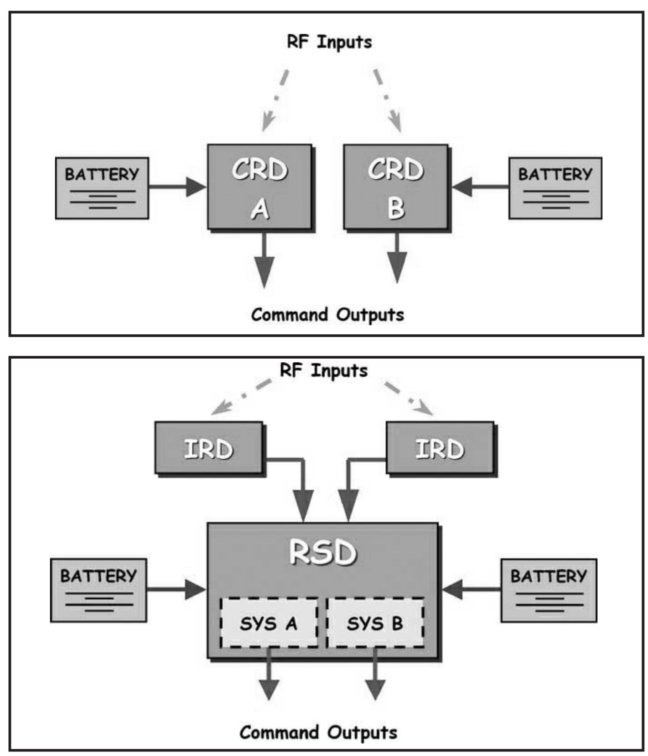
The most advanced, secure range safety technology available, the Solid Rocket Booster Project's command receiver decoder (CRD), has completed the development and qualification phase and has moved into production. The first flight set is scheduled for delivery in fiscal year 2002. The CRD replaces the integrated receiver decoder (IRD) and the range safety distributor (RSD) of the Range Safety System.



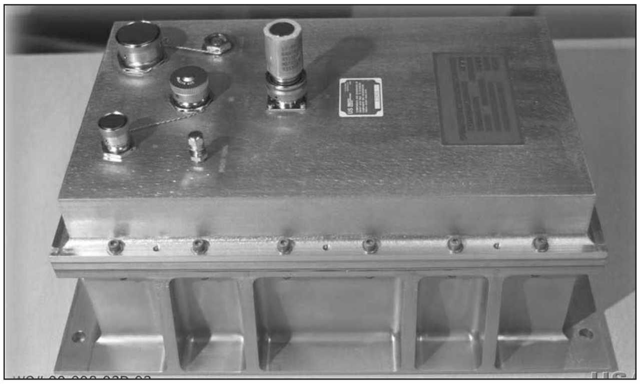
SRB's New Command Receiver Decoder

The CRD Project was initiated because of a hardware supportability threat due to electronic component obsolescence. A replacement concept, which combined the IRD functions with the distribution functions of the RSD, was selected because it provided a simplified system, reduced weight, and eliminated a line replaceable unit.

The CRD design addresses obsolescence issues and increasing maintenance and supportability



Comparison of IRD/RSD and CRD Configurations concerns in the current IRD / RSD fleets. Supportability was designed into the CRD to lower operations costs by simplifying installation, testing, and refurbishment. The design effectively eliminates a line replaceable unit and the associated vendor sustaining engineering, test set, and logistics costs.



New SRB Radar Tracking Controller Successfully Flown on STS-100

The Solid Rocket Booster Project successfully flew the C-band controller (CBC) for the SRB radar beacon tracking system (SRBTS) on STS-100. The SRBTS provides enhanced performance for the C-band tracking radar. The C-band radar is one of three redundant vehicle tracking methods used for the Space Shuttle. The CBC was designed, certified, and manufactured as an in-house United Space Alliance and Marshall Space Flight Center project.

The CBC design consists of an upper housing, which contains electronics and input/output connectors, and the lower housing, which contains an integrated battery power supply. The lower chamber can be opened to change the internal alkaline battery pack without exposing or disturbing the electronics.

Using commercial-off-the-shelf (COTS) Mil Spec components and technology for the selection of batteries, components, and connectors, the CBC provided an immediate cost savings of $20,000 per flight compared to the existing system. Other improvements include simplified manufacturing and improved reliability. Another performance gain of the CBC is the weight reduction of approximately 480 pounds per flight (240 pounds per booster).

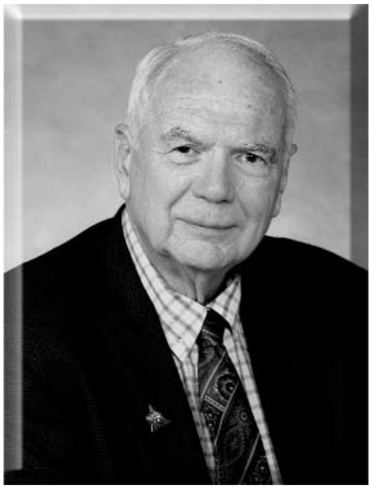
In summary, the CBC was designed with COTS hardware resulting in inexpensive but reliable flight hardware that will transport us well into the 21st century.

SRB Independent Operations Assessment Team (IOAT)

The SSP requested each Space Shuttle project select an independent team to assess their hardware operations. The SRB Project selected an independent team with the prime objective to review the use of reusable hardware. Specifically, the team addressed the refurbishment and acceptance requirements/screens, maintenance procedures and instructions, and developed recommended actions to mitigate concerns of aging, wear, and tear. The team initiated its effort in January 2001 and presented findings and recommendations to the Shuttle Program Manager in May.

The IOAT concluded SRB operations "are well postured to support the Space Shuttle Manifest in the foreseeable future" with the implementation of recommended actions. The recommendations focused on enhancing the use of trending and statistical process control; performing periodic reviews of operational requirements based on past experience and data; assessing the requirements and plans for vendor audits; revisiting the responsibilities involved in the procurement of parts and materials; reassess the use of finger printing materials for aging, wear and tear; and reevaluating inspection, repair, and maintenance practices.

To further enhance SRB hardware reuse, the SRB Project decided to develop an SRB Hardware Reuse Plan. The purpose of this plan is to capture and describe reuse requirements, processes, and procedures. This will allow development of proactive plans to mitigate reuse concerns for the life of the Space Shuttle. ◆



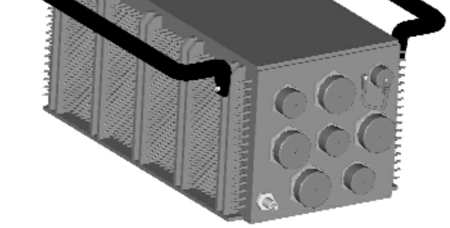
George D. Hopson, Manager,
Space Shuttle Main Engine (MSFC)

SSME Health Management Upgrade Will Reduce Risk 40%…

The advanced health management system (AHMS) is a two-phase safety upgrade project that will reduce Space Shuttle Main Engine (SSME) catastrophic ascent risk by more than 40%. This risk reduction comes through the application of improved high-pressure turbopump vibration sensing technology combined with advanced health management algorithms, engine modeling, and real-time signal processing technology. Additionally, implementation of AHMS Phase 2 will introduce two new potential mitigation actions for SSME failures – single engine throttle-down and mixture ratio adjustment. These failure mitigation actions, when taken in lieu of engine shutdown, will enable the Space Shuttle to achieve a safer abort mode or possibly even turn what would otherwise be an abort into a successful mission.

AHMS Phase 1, which focuses on upgrades to the existing SSME controller, made significant progress in 2001. The detailed design effort culminated with the on-schedule conduct of the Critical Design Review in May 2001. The new AHMS Phase 1 circuit card assemblies were then successfully fabricated and assembled into the existing Honeywell controller brassboard unit. An integrated system-level test was subsequently performed on this brassboard with only minor problems identified and corrected. A second brassboard, used for flight software verification and validation, will be retrofitted and delivered in November 2001. A development unit, suitable for use in engine hot-fire testing, will be retrofitted and delivered in May 2002. AHMS Phase 1 remains on schedule for a first flight in May 2004.

AHMS Phase 2, which consists of the design, development, and implementation of a new health management computer (HMC) system, shown in figure, also made significant progress in 2001. Detailed trade studies and analyses were conducted with the results folding into the baseline system concept of operations document and Space Shuttle Program requirements. A Program Requirements Review was successfully conducted in November 2000 with a Systems Requirements Review following in February 2001. A final System Definition Review was held in August 2001 to confirm that the conceptual design for Phase 2 met established requirements. Phase 2 formulation activities will conclude at the end of this fiscal year.



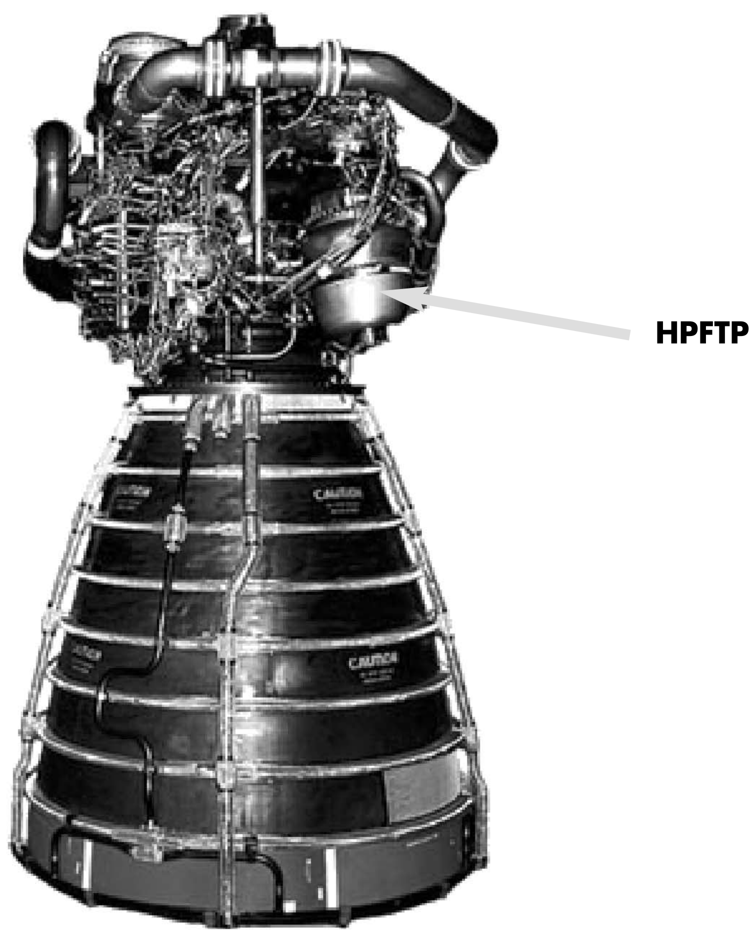
HMC Figure

Block II Space Shuttle Main Engine First Flown on STS-104

On July 12, 2001, the world heard the roar of the first Block II SSME when it flew for the first time on STS-104. The maiden flight was a single Block II engine clustered with two Block IIA engines. The next Block II flight will be November's STS-108, which again will have only one Block II engine. All flights subsequent to STS-109 will be flown with Block II engines in all three Orbiter positions.

The Block II engine is an upgrade from the Block IIA engine, which has been flying since STS-89. The most significant improvement is the new Block II high-pressure fuel turbopump (HPFTP). This turbopump replaces the HPFTP used on both the Block I and Block IIA SSMEs, which served the program very well since the first Space Shuttle flight, STS-1 in 1981. The Block II HPFTP improves the engine reliability, safety margins, and life and reduces maintenance and overhaul costs. Because of the Block II HPFTP's incorporation, the reliability of the SSME improves 28% relative to Block IIA. Extensive use of investment castings eliminated 469 welds in the previous design and eliminated all flow path sheet metal shielding. An improved bearing design completely eliminated wear issues and increased the load capability for rotor support. The rotor system is very stiff, and with improved balancing techniques, the synchronous vibrations are reduced by a factor of 2 to 4. The single-piece rotor and disk along with the robust bearings result in a turbopump that is very tolerant to damage. ◆

For more information concerning the SSME Program and its evolution, please refer to AIAA paper: AIAA 2001-3417, "Space Shuttle Main Engine Evolutions."



G. Allen Flynt, Manager,
EVA Project Office (JSC)

New High-Tech Gloves are a Revolutionary Step…

Since the early 1980's, the Space Shuttle extravehicular activity (EVA) glove design has evolved to meet the challenge of space-based tasks. These tasks have typically been satellite insertion and retrieval or EVA-based flight experiments. With the start of the International Space Station (ISS) assembly, the number of EVA-based missions is increasing far beyond what has been required in the past. The introduction of the ISS has also increased the difficulty of EVA tasks and the hand mobility and tactility needed to complete those tasks. The success of astronauts in performing EVA is highly dependent on the performance of the space suit gloves they are wearing.

By the early 1990's, the 4000 Series glove and its performance had evolved as far as the basic design would allow. It was determined that merely an evolution of the current 4000 Series glove design would not meet future mission objectives. In an attempt to make a revolutionary step in glove design for ISS assembly, a completely new glove was developed that retained little of the previous design except for some of the materials technology

Phase VI Glove

The Phase VI glove is the first EVA glove to be developed completely with computer-aided design. As with previous designs, the custom size development process starts with a hand cast; but beyond that the Phase VI processes depart drastically from those of the previous design. The Phase VI glove design includes laser scanning technology, 3D computer modeling, stereo lithography, laser-cutting technology, and CNC machining. It is through the use of these advanced technologies that a custom glove size can be developed faster, with higher accuracy, and at a lower cost than previous glove designs.

With this advanced capability, significant effort was placed in determining minimum easements for the construction of the glove. This translated into lower volume in the glove and, therefore, less expended user effort when compared to existing designs. A minimum easement bladder/restraint system was developed. This resulted in an integrated bladder that exhibits virtually no wrinkles and provides a very comfortable, conformal glove.

The Phase VI hand is designed to be anthropomorphically correct to the crewmember's hand. Using pleated, lightweight polyester fabric, the fingers and thumb mobility joints are designed as all fabric assemblies to decrease torque and increase fingertip tactility.

Phase VI gloves are now certified to provide up to 19 EVAs of on-orbit use as compared to 8 EVAs for the 4000 series. Phase VI gloves have successfully supported all EVAs since September 2000.

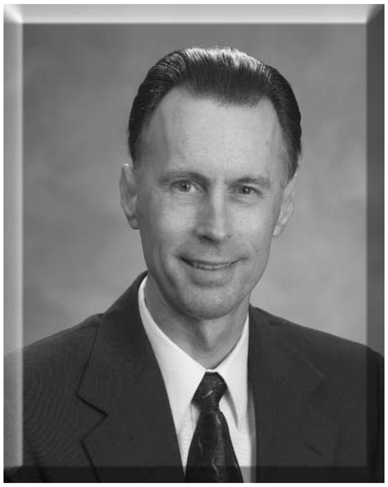
Increased Capacity Battery

ISS mission logistics required an extravehicular mobility unit (EMU) battery with increased shelf and cycle life. To support the increment crewmembers ability to perform EVAs from the ISS, the EMU and its battery must be capable of 25 EVAs performed over a 365-day period. An additional 60 days of shelf life must be available to cover EMU preparation time and potential launch delays. These mission requirements translate to a battery with 425 days of wet life that is capable of 32 charge/discharge cycles.

Increased Capacity Battery

The original Space Shuttle EMU battery is capable of only 170 days of wet life and 6 charge/discharge cycles. This design is compatible with the relatively short Space Shuttle missions, but it is incompatible with long-term support of an autonomous ISS.

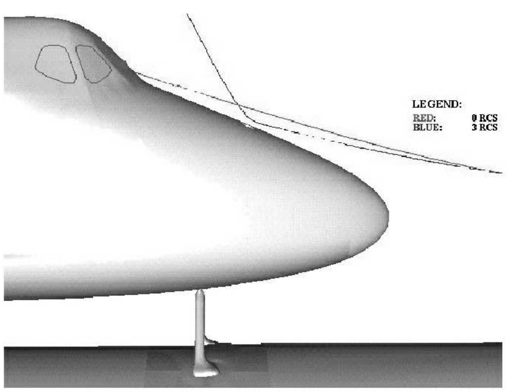
Both the original and the increased capacity battery are built from 11 individual battery cells assembled into a single battery. Capacity was upgraded by increasing the individual cell size. Shelf life was increased by improvements to the cellophane material that separates the positive and negative electrodes within the battery. The rate at which this cellophane degrades with each charge/discharge cycle dictates the battery cycle life. These improvements have resulted in 250% increase in wet life and 500% increase in cycle life. These increases were accomplished with only a 1-inch width change to the battery and a 5-pound weight growth. There is no change to battery mechanical or electrical interfaces. This increased capacity battery, which also replaces the batteries used on the Space Shuttle, was successfully demonstrated by providing power for two successful EVAs on STS-100 (6A) in April 2000. ◆



Lambert D. Austin
Manager, Systems Integration (JSC)

Advanced Separation Technique Saves Thousands of Processing Hours…

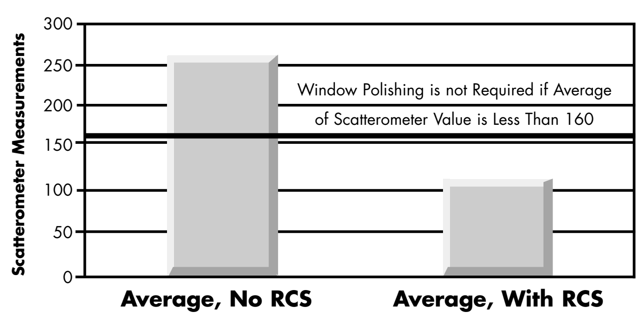
After each mission, the Orbiter windows require 500 work-hours of polishing to restore them to flight condition. Review of launch films and extensive flow-field analysis revealed that the booster separation motor (BSM) plume impingement onto the windows was the most likely source of the debris that caused the windows to micro-pit and haze. Computed aerodynamic flow fields for the vicinity of the Orbiter's nose indicated that the high pressure of the forward reaction control system (RCS) jets, when firing simultaneously with the BSM firing, would be sufficient to deflect BSM particles away from windows.



Simultaneous RCS and BSM firing have been successfully used since STS-98. An optical instrument known as a scatterometer measures the pitting and the results are used to determine the requirement for postflight window polishing. Measurements from the first four flights (STS-98, -102, -100, and -104) show significant reduction in the amount of hazing and pitting, thus eliminating the cost of polishing.

This modification also resulted in improved visibility for the astronauts, a decreased risk of window failure, and a reduced cost of window replacement.

Scatterometer Data With and Without RCS Jet Firing

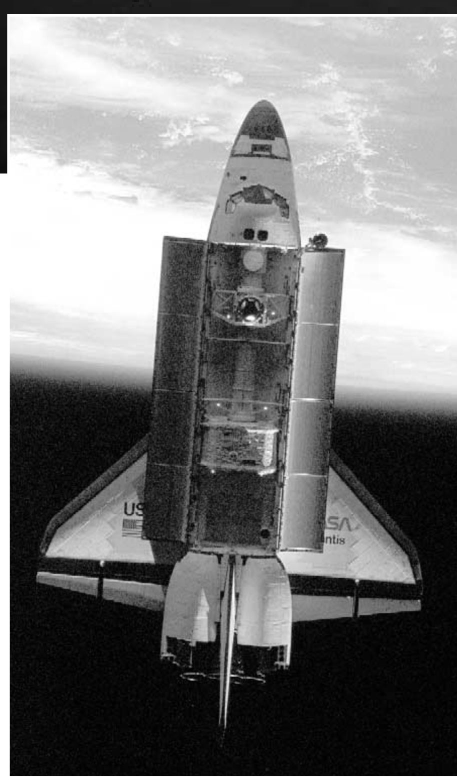


SSP Electromagnetic Requirements

The Space Shuttle electromagnetic requirements were recently updated to reflect state-of-the-art electromagnetic interference test techniques and to set limits based on the electromagnetic environment experienced during vehicle operations. The new electromagnetic requirements reflect interference and susceptibility concerns specific to the Space Shuttle. To determine the new susceptibility test limits and external electromagnetic environment, the Joint Spectrum Center accessed numerous ground-based emitter databases and computed the magnitude of the electromagnetic field at the vehicle for typical ascent, on-orbit, and descent flight profiles. Control procedures for each of the high-power ground-based emitters, with the potential to exceed the current control levels, were reviewed to verify that adequate controls were in place. The box-level susceptibility test limits were raised to verify operation at the maximum.

Shuttle Improves Manifesting Flexibility to Support ISS

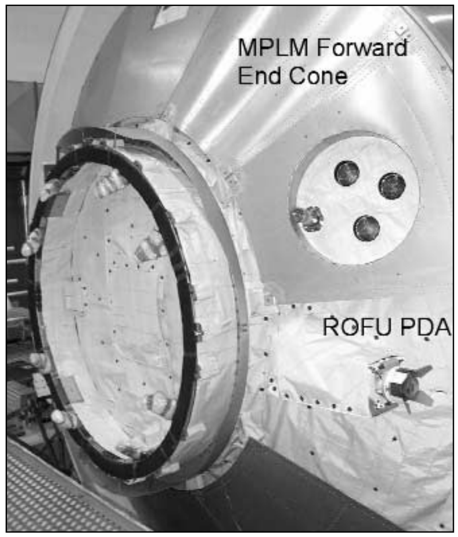
For each Space Shuttle flight, a mission-specific structural analysis is conducted to verify that the compliment of payloads manifested and the predicted flight environments are within the structural capability of the Orbiter. These analyses only protect for minor changes after the dynamic math models are submitted $7\frac{1}{2}$ months prior to launch. For ISS logistics flights, additional flexibility is required to support changes late in the flow.



ISS Logistics Flight with an MPLM and an Integrated Cargo Carrier (ICC)

The SSP evaluated current capabilities and improved the weight distribution and the loads analysis process to add flexibility for future missions, including SpaceHab, MPLM, and unpressurized payload bay carriers.

The analysis evaluated 101 liftoff and landing combinations of ICC and MPLM configurations in an attempt to significantly increase the existing 200-pound change tolerance. This study showed that for a large range of ICC and MPLM weight and center of gravity (CG) configurations, the Orbiter interface capability was not exceeded.



Work is currently in progress to determine the sensitivities between the SpaceHab Logistics Double Module and the ICC. A total of 50 liftoff and landing combinations will be evaluated. This work is expected to be completed at the end of January 2002.

The ISS stowage racks within the MPLM have been identified as extremely sensitive to weight and CG changes, requiring extensive analysis for most any change. The ISS has developed a plan to analyze, test, and modify the racks, as required, that will result in increased capability and, therefore, increased flexibility.

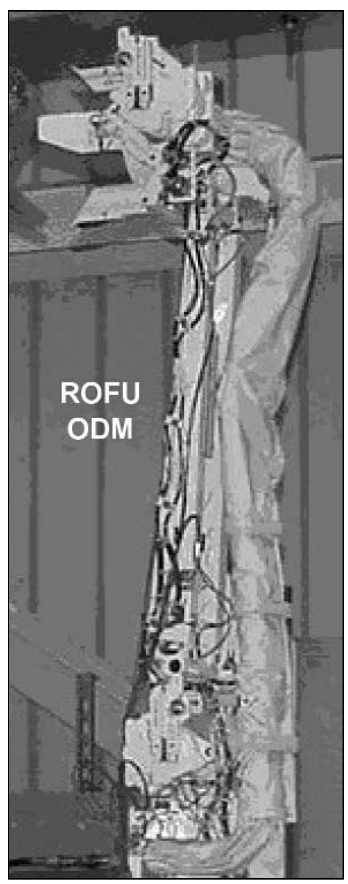
Although significant progress has been made in providing greater manifest flexibility to the ISS for outfitting and logistics flights, the SSP and ISS are continuing to develop plans and processes that will allow additional flexibility to be implemented with less analysis.

New Capability For ISS Missions

Qualification testing of the new remotely operated fluid umbilical (ROFU) system has recently been completed. The ROFU system provides a remotely connectable and disconnectable fluid interface for deployable payloads that require cooling while in the Orbiter cargo bay. The first user will be the ISS MPLM, which will begin using the ROFU on ISS mission UF-3.

The ROFU is based on the remotely operated electrical umbilical (ROEU) design that was built and certified in the 1980's. Early in the ISS Program, it was identified that a disconnectable/reconnectable cooling capability would be required. To satisfy this new requirement, ROEU plumbing and wiring modifications were incorporated while still retaining the basic structure and electromechanical actuators.

The ROFU, which is similar to the ROEU, consists of two parts: the Orbiter disconnect mechanism, which is mounted on an Orbiter payload bay longeron bridge; and the payload disconnect assembly (PDA), which is permanently attached to the payload or cargo element.



Certification of the hardware has been completed. Both flight units will be delivered by April 2002. ◆

Michele A. Brekke, Manager,
Customer and Flight Integration (JSC)

Streamlined Documents, Multimedia Tools Improve Customer Service…

The Space Shuttle Customer and Flight Integration Office completed an initiative to create an enhanced environment for new payload customers. The existing documentation set was streamlined, and products were created to guide customers though the payload integration process.

Two products were developed to allow the customers easier access to payload documentation. One is a compact disk (CD) that can be used as a familiarization tool. This interactive tool provides a high-level, conceptual overview of the integration process. Copies can be obtained by contacting Customer and Flight Integration, 281-483-3543.

The second product is the payload information website. This website can either stand alone or work in conjunction with the CD. The information is organized to guide the customer through the payload integration process with more detail than is captured in the CD and with hyperlinks to required payload requirements documentation. The website is located at http://shuttlepayloads.jsc.nasa.gov ◆

Ralph Roe, Manager,
Space Shuttle Vehicle Engineering (JSC)

User-Friendly Cockpit Will Increase Safety by Reducing Workload of Space Shuttle Pilot…

Piloting the Space Shuttle requires a unique, complex interaction between human and machine. When every automated system is working correctly, the crew still has plenty of work to do, monitoring the vehicle, its trajectory, and its systems. The crew must be ready to take action at a moment's notice, in response to a wide range of possible malfunctions and failure scenarios, to ensure the continued safe operation of the vehicle. In some scenarios, the crew has less than 15 seconds to decide whether to continue the mission or to perform a challenging abort maneuver.

Today, when a system failure occurs, generic alarm tones and lights alert the crew. The crew then has to actively seek out details about the failure by calling up numerous displays that are often filled with complex raw data in numerical form. Unfortunately, all this sleuthing requires a high degree of crew skill and concentration. And, the net effect can be that the crew's attention is drawn toward the failure and away from the demanding job of controlling the vehicle. This effect, the loss of what the crew calls "situational awareness", has been identified as a critical safety issue facing the Space Shuttle Program (SSP) today. Closing the SA gap in the Space Shuttle cockpit is the focus of the cockpit avionics upgrade (CAU) program.

CAU will provide both the connectivity and the processing power needed to access, analyze, and summarize the streams of raw data, and to present this summary to the crew in a very readable, user-friendly format. With CAU, pages of cryptic text and numbers will be replaced with pictures and graphs. Colors and symbols will be used to reveal anomalies at a glance. Caution and warning messages will appear in plain English on a centralized display screen. Any one of more than 100 different displays will be reachable with no more than 4 keystrokes, starting from a top-level menu.

Best of all, each display will not only give information, it will also take commands. In today's system, the crew might have to switch several times between one display, to gather data, and another display, to enter command inputs. CAU will consolidate information display, and command input functions into single, task-oriented display formats.

Perhaps the most striking example of this improvement is during launch aborts. In today's system, the crew must constantly monitor propulsion performance and vehicle energy (speed). In the unlikely event of a significant failure, the crew must first note the time of failure, the energy, and the position of the vehicle as well as particulars of the failure itself, such as whether one or more engines failed. All these data comes from different displays and instruments throughout the cockpit, except Earth-relative position, which is not displayed anywhere.

A new horizontal situation display will

provide all the necessary information in one place. Energy and performance calculations will run continuously in the background, while the crew will see a simple Earth map showing the Space Shuttle's trajectory in relation to all available abort destinations. As destinations move into range, their color will change to show they can be reached with all three, then two, then only one working engine. The color will change one last time to show that the Space Shuttle's growing speed has put the closest destinations out of reach. Using just this one new display, the crew can monitor performance, select the best available abort destination, and command the Space Shuttle to fly to that destination.

CAU is projected to fly for the first time in the year 2006.

Electric Auxiliary Power Unit Upgrade

The Orbiter today contains three hydrazine-fueled auxiliary power units (APUs) that maintain hydraulic pressure to operate a variety of aerosurfaces, the umbilical retractors, the landing gear, and the brakes. The toxic and flammable hydrazine propellant, along with the high-speed turbine used in the APU, account for approximately 30% of the overall Space Shuttle risk. A replacement for the hydrazine APUs, called the electric auxiliary power unit (EAPU), has been authorized for advanced development and prototype testing.

In July 2001, a complete prototype EAPU system was successfully tested. This prototype system was powered by a one-third scale battery rack. A power distribution and control system interfaced the battery with an electrohydraulic drive unit (EHDU), which included the motor, controller, inverter, and pump that converted electric power to hydraulic power. The EHDU was connected to a hydraulic load bank that simulated Orbiter hydraulic flow profiles. A modified water spray boiler provided cooling to the hydraulic fluid and to the EHDU electronics. This testing demonstrated the system capability of the prototype EAPU to meet normal profile requirements and off-nominal EAPU failure profiles.

With a majority of the cell and battery testing complete, preliminary results show this cell to be very robust and easily capable of meeting EAPU requirements.

The Cockpit Avionics Upgrade

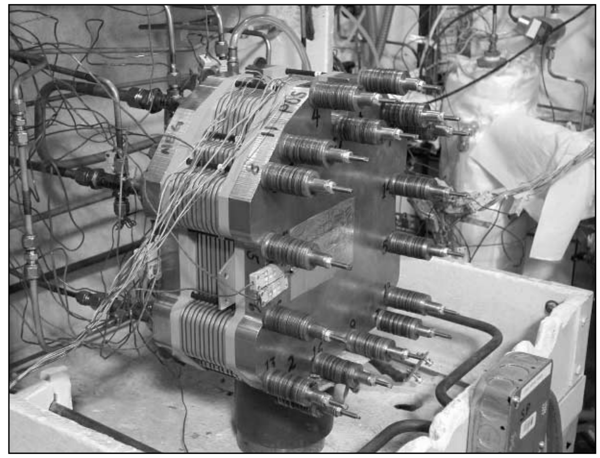
Two vendors were contracted to build prototype EHDUs and cooling systems. Both vendors successfully completed acceptance testing and hardware delivery. Both prototype systems demonstrated capability to meet the normal 70-gpm and contingency 90-gpm hydraulic flow profiles. Additional work is scheduled for fiscal year 2002 to advance selected technology and identify cost and weight savings options.

Long Life Alkaline Fuel Cell (LLAFC) Upgrade

In February 2000, the SSP authorized the design, fabrication, and qualification of the LLAFC. Improvements to the power plant have been authorized to increase the operational life from the current 2,600 hours to 5,000 hours. These improvements include enhancements to the individual cell design (to reduce frame corrosion), more durable external seals, non-cracking insulator plates, a stainless-steel regulator housing, integrated single-cell sensing electronics, a metal bellows coolant accumulator with quantity sensor, and hydrogen/oxygen pressure sensors.

Individual cell testing was completed to select the most promising cell designs. These cell designs were then verified by the use of 10-cell development test rigs operated at higher temperatures to accelerate corrosion/analysis. Finally, a 10-cell endurance test rig was made to verify the cell designs at standard operating temperature and pressure. The 5,000-hour endurance test was successfully completed in November 2001.

A 96-cell qualification test article is scheduled to begin testing in January 2002. This test article will include the improved cell design, ancillary components, and enhanced instrumentation. Upon successful completion of the 5,000-hour test, the LLAFC will be certified and made available for installation into the fleet beginning in 2004.



Developmental 10-Cell Endurance Test Rig

Main Landing Gear Tire and Wheel Assembly Upgrade

One of the safety improvements initiated by the Space Shuttle Vehicle Engineering Office (SSVEO) is an upgrade to the main landing gear tire and wheel assembly. The upgrade is intended to add 20% additional load-carrying capability to the tire and wheel. The initial activities in CY2000 and CY2001 focused on the iterative process of tire design and testing, which will result in a selection of the specific design for production in early 2002. The upgraded tire and wheel assembly will be integrated into the Orbiter fleet in 2003.

The initial tire testing evaluated nine different tire designs. Testing at Wright Patterson Air Force Base has completed pre-roll cycles on 54 tires, and 42 dynamic test cycles on 8 of the 9 tire designs. Of the eight designs tested, four have survived dynamic load cases at 171,000 pounds, which meets the program goal of adding 20% load-carrying capability. Testing at Langley Research Center (LaRC) determined that the new tire designs have slightly better cornering capability than the current Space Shuttle tire. The photograph on page 45 shows a tire test run at the

LaRC facility. The test equipment propels the tire down a 1,500-foot runway at speeds up to 220 knots, with the ability to vary tire yaw. Critical speed and burst testing have also been recently initiated.

Tire Test Facility at LaRC

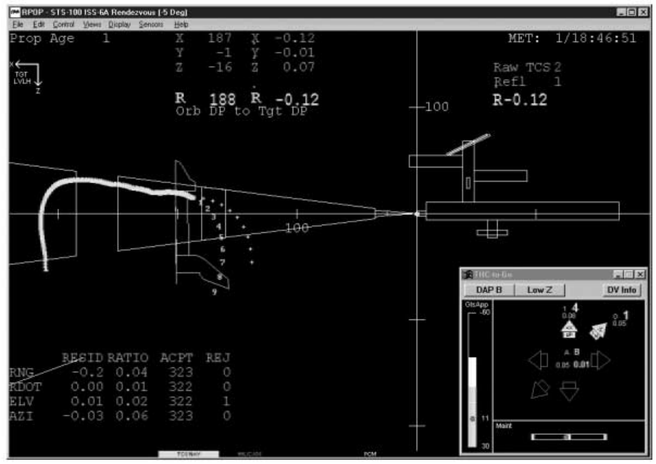
Avionics and Software

Numerous software upgrades have been implemented this year. Some of the highlights include abort capability improvement, program upgrades support, and operational improvements.

Abort system improvements included increasing the number of available landing sites, flight control changes to eliminate or reduce black (non-survivable) zones, short-field landing site capability implementation, and automation of contingency maneuvers.

Several program upgrades were supported, including the Space Shuttle main engine advanced health monitoring system, the Cockpit Avionics Upgrades (CAU) project, and the Cargo PC.

Another capability that has been added this year is automated Space Shuttle reboost. During early International Space Station (ISS) assembly flights, reboost was accomplished through manual techniques that required the crew to input precisely timed thruster firing commands that minimized structural loads on the ISS. These manual techniques engaged two or three crewmembers for up to 1 hour. New algorithms were developed and implemented in the onboard flight control software that generate automatic



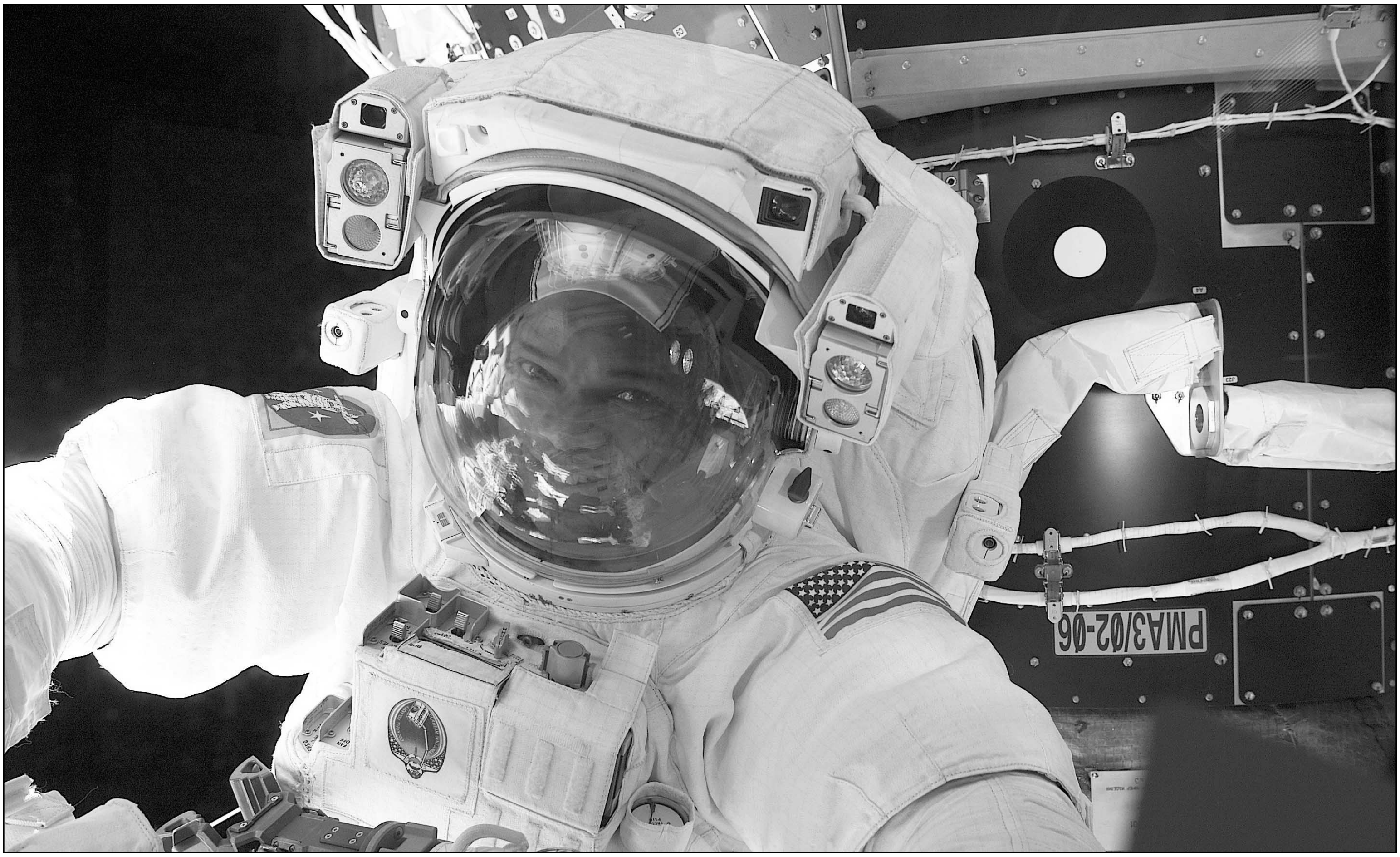
timed commands while monitoring and correcting for attitude errors. Through STS-104, Space Shuttle reboost has increased the ISS altitude a total of 172 km, resulting in an ISS propellant savings of 2,800 kg, or the equivalent of two Progress refueling missions.

Since 1993, the Rendezvous and Proximity Operations Program (RPOP) application on the payload and general support computer (PGSC) has provided enhanced situational awareness to the crew during the rendezvous, proximity operations, separation, and flyaround maneuvers. New proximity operations guidance algorithms for the RPOP were first flown on STS-100. An actual PGCS screen display of the RPOP application used during STS-100 is shown in the figure above.

The new guidance algorithms offer specific translational jet firing suggestions during V-bar acquisition and approach, including out-of-plane control guidance. The goal is to achieve more tightly controlled and repeatable trajectories, along with a simultaneous reduction in propellant consumption of as much as 25 pounds.

Wireless Video System (WVS)

The SSVEO developed an extravehicular activity (EVA) video system to provide high-quality, hands-free viewing for the crew in the cabin and for ground personnel for closeout documentation and troubleshooting of Space Shuttle and ISS assembly tasks.



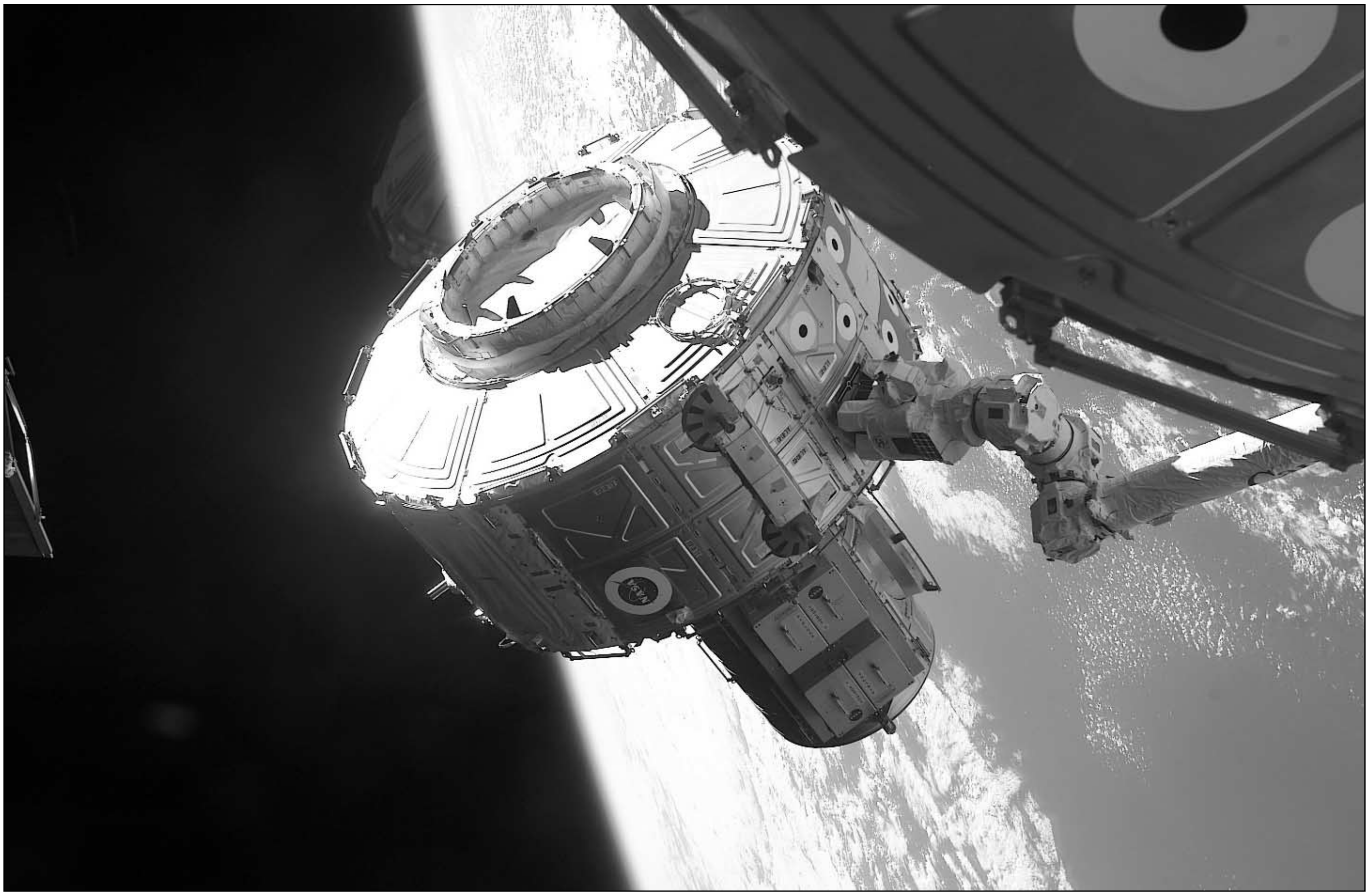
STS-98 Astronaut Bob Curbeam and the WVS

Three radio frequency cameras are installed on the extravehicular mobility unit (EMU) helmet. The helmet also contains an ultra high frequency antenna for camera and aperture commanding from the intravehicular activity crewmembers and two S-band antennas to transmit video images back to the Orbiter.

On its first flight, the WVS was used extensively to document assembly tasks and to evaluate solar array deployment issues encountered during an EVA, saving valuable crew time. WVS will continue to be an invaluable resource for the SSP through the ISS assembly missions, Hubble Space Telescope servicing missions, and other future EVAs.

Space Vision System (SVS)

The SVS has provided robotic positioning cues during the last seven missions to the ISS. The cues supported major element mating operations on ISS Assembly Flights 3A, 4A, 5A, 5A.1, 6A, and 7A, and ISS multipurpose logistics module re-supply operations on Flights 5A.1, 6A, and 7A.1. The value and importance of the SVS technology to the SSP was especially evident on STS-104/7A where SVS was the primary cue for the installation of the airlock onto the ISS. The SVS was designed and built by Neptec Design Group of Ottawa, Canada, under NASA contract to the SSVEO. The SVS processes video signals from television cameras mounted on the Space Shuttle or the ISS. It analyzes the locations of target “dots” on the elements to be mated to precisely determine the relative position and orientation of the elements. The SVS then displays six degree of freedom cues on television monitors to enable astronauts operating the robotic manipulator to accurately position the elements.



STS-104/7A Airlock Assembly

Orbiter Remote Manipulator System

During fiscal year 2001, the SSVEO completed an extensive overhaul and upgrade of the oldest and most frequently used remote manipulator system (RMS).

The original arm was successfully disassembled, inspected, refurbished, and re-tested. New and improved motors, brakes, and joint position sensors were installed and each of the arm's six gearboxes were removed and overhauled.

The redesigned brake units that were installed employ a new fade-resistant ceramic friction material. The new ceramic brakes provide more stable on-orbit braking performance than the previous design. A new bearing design was also used to reduce the brake's running friction, which will extend motor life.

As part of the joint motor build, new optical commutators were incorporated. The new commutators use mirrors and lenses (instead of delicate fiber-optic bundles) to move light from the light-emitting diode light source to the electronics. This improves system reliability and reduces the risk of handling damage.

As a result of the refurbishment, the life of arm 201 has been extended and the near-term risk associated with unscheduled downtime due to a hardware failure has been reduced. Additionally, the running friction of the arm's joints has been reduced. Lower joint friction will result in reduced power consumption and improved handling performance.

This refurbishment effort is part of a strategic long-term investment to ensure the continued reliability of the RMS system through the year 2020. ◆

Jon C. Harpold, Director,
Mission Operations (JSC)

Astronaut, Flight Controller Training Takes Technological Leap…

…with the implementation of off-line, desktop training simulators. The current era of the International Space Station (ISS) assembly flights has increased the pace of new development, real-time operations and personnel certification requirements. Together, these have placed competing demands for resources on mission-critical facilities used in flight controller and astronaut training. Such constraints to facility access are now challenging the Mission Operations Directorate (MOD) to efficiently complete all of the required training and certifications for astronauts and flight controllers assigned to support upcoming missions.

With current desktop workstation technologies, speed and value in computer hardware coupled with the maturity of Space Shuttle and ISS simulation applications have enabled two facilities in particular to meet crew and flight controller needs for position certification and skills proficiency training: the flight controller trainer (FCT) and the dynamic skills trainer (DST).

The FCT is a standalone mission control center (MCC) workstation simulator used to train flight controllers in Space Shuttle single- and multi-system malfunction diagnosis and recovery in a real-time operations environment. FCT lessons are taught one-on-one between a student and an instructor or mentor. The lessons cover nominal operating procedures, failure identification, system troubleshooting and reconfiguration, and end-of-mission impacts assessment.

A next-generation flight controller trainer (NGFCT) is in development to significantly enhance the capabilities of this facility with a simulation that combines a Space Shuttle general purpose computer emulator (GPCE) with systems and environment models from the existing Shuttle mission simulator (SMS). The resultant training platform, which will be available in fiscal year 2002, provides higher fidelity and supports vastly increased malfunction and multi-system training scenarios with minimal new software development. With GPCE, flight controllers can participate in a simulation running actual Space Shuttle flight software in a part-task training environment at a fraction of the operating costs associated with SMS/MCC integrated training.

The development goal is for all Space Shuttle systems and robotics disciplines to meet the majority of their position certification training objectives in the FCT environment. The NGFCT can also be used to conduct "mini-sims," with a single simulation driving two NGFCT consoles for different flight control disciplines.

The DST is a desktop workstation that allows students to run a variety of man-in-the-loop simulations of Space Shuttle and ISS flight activities. The DSTs are used for introductory or proficiency training in tasks requiring careful hand-eye coordination; e.g. Shuttle rendezvous and proximity operations, ascent/entry piloting techniques, and both Shuttle and ISS robotics operations.

DSTs have been installed in several Johnson Space Center facilities, enabling students to train at their convenience, with or without an instructor's assistance. Each workstation consists of two monitors, two central processing units, and a set of translational/rotational hand controllers. The workstations supporting these trainers provide high-fidelity simulation of Space Shuttle systems, flight dynamics, and other environmental characteristics; flight software emulation; representative cockpit instruments and computer displays; and complex out-the-window visual scenes.

Together, the DST and FCT provide high-powered simulation capability with the potential to significantly offload training requirements from the SMS and the MCC. With continued development and enhancements to each of these facilities, MOD will have inexpensive and portable alternatives for assuring the successful completion of all training requirements as astronauts and flight controllers work to achieve the ambitious goals of the Shuttle Program.

Replacing the Old with the New

MOD personnel are in the final stages of replacing the old mission operations computer (MOC) mainframes in the MCC with newer, UNIX-based technology.

In 1997, the Trajectory Subsystem Upgrade Project (TSUP) was authorized to proceed with a very focused scope. TSUP was limited to the direct re-host of the existing Assembly language to C language, with a very limited set of requirements changes, using the traditional MOC software development processes. The MOC Trajectory subsystem had almost 1,000,000 source lines of code, constituting over 75 "number crunching" applications.

MOC main frame computer

In FY2002, the mainframe will be replaced with high-performance UNIX servers on the MCC distributed network. The project is undergoing operational readiness tests to ensure readiness for simulations and final flight certification. The new system is targeted to provide primary mission support for STS-110 in 2002, with the MOC available as a back-up. After several missions, the MOC back-up capability will be removed. The deactivation of the mainframe computers will provide a significant cost savings. ◆

David A. King, Director
Shuttle Processing (KSC)

Multiple Enhancements Boost Safety, Processing Capability…

SYSTEMS CONTROL AND MONITORING

The Kennedy Complex Control System (KCCS) currently under development to replace the facility control and monitoring systems will reduce maintenance cost and increase system interface capabilities.

HAZARDOUS GAS DETECTION SYSTEM (HGDS) 2000

The first production unit of the new HGDS 2000 has been installed in mobile launch platform (MLP) 2 for validation and operational use for STS-109. It exceeds the capabilities of the legacy prime HGDS in its generation of data, its versatility, and its ability to operate in an air environment, as opposed to requiring a nitrogen environment, without degrading the equipment.

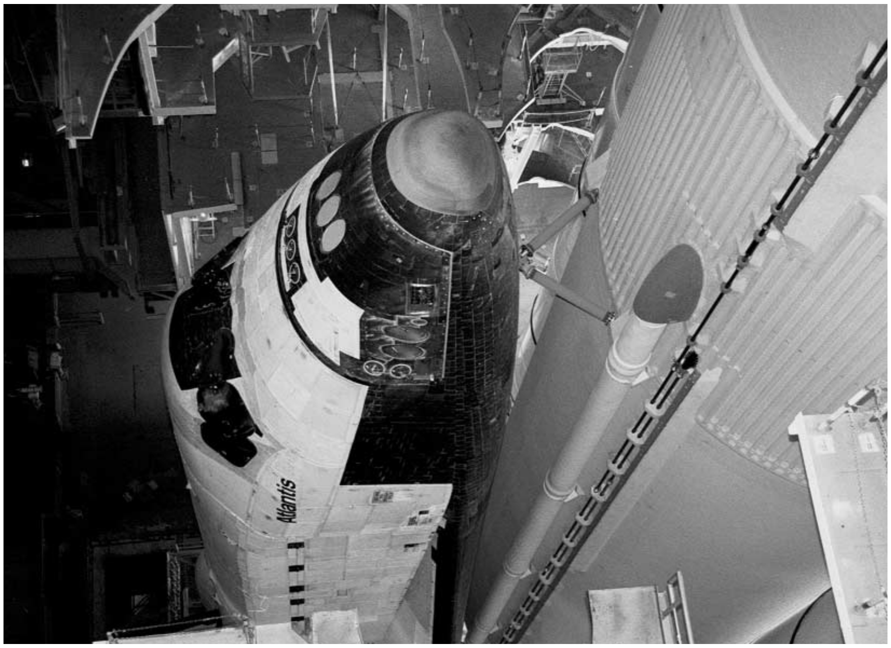
The performance of the new system has been excellent, and deployment of the system is continuing to the remaining MLPs in support of STS-110 and STS-111.

CHECKOUT AND LAUNCH CONTROL SYSTEM (CLCS)

The CLCS is being developed to replace the existing launch processing system (LPS) used to launch the Space Shuttle. The CLCS provided its first operational support at the Hypergolic Maintenance Facility (HMF) at Kennedy Space Center in August 2000. CLCS completed the operational readiness review for the full HMF capability, including the aft propulsion system, in December 2001. In addition, the cargo integrated test equipment set and Shuttle Avionics Integration Lab set at the Johnson Space Center were installed and tested this year.

THE CENTRAL OPERATIONS FACILITY (COF)

The COF was activated November 17, 2000. The COF provides 24-hour support of the Shuttle Data Center, the LPS operational network and the CLCS inter-set network. The COF



supported operations for the STS-97 launch countdown processing as scheduled. The Emergency Operations Center also moved to the COF, which allows co-location of duty officers, the test conductors, and the test director for emergency hurricane operations, which enhances communication and responsiveness to the safety of our workforce and Orbiter vehicles.

Standby to Stack

Work is under way to modify the Vehicle Assembly Building to allow a processed Orbiter with a standard payload to be stored for up to 180 days prior to being mated to the external tank. Some of these modifications are the design and installation of platforms, piping, portable lighting, communications, humidity control enclosure, and LPS.

Storage Improvements

Previously, solid rocket boosters were being stored on railcars just south of Launch Complex 39 when they arrived from Utah. This left the railcars vulnerable to a severe lightning storm or hurricane, which could create a hazardous situation for workers in the area. A new capability to store the railcars at a remote location has been added, and maximum railcar storage will increase from 5 to 14.

Simulation Tier Training

The tier training project was developed to provide engineers system training in a launch environment. It consists of Tier 1 simulations, involving only one system at a time, and Tier 2 simulations, which combine similar systems to work integrated problems. The simulation begins anywhere from T-3 hours to T-20 minutes, depending on the system and the purpose of the training.

Orbiter Roll-in Laser Alignment System

A low-cost laser system used for aligning Orbiter tugs during roll-in to the Orbiter Processing Facility (OPF) was developed and assembled. The system simplifies the task and reduces the time to align and roll the Orbiter into the OPF from over 4 hours to less than 15 minutes.

Foreign Object Damage/Debris (FOD) Observation Pilot Program

A pilot program that identifies FOD on the basis of risk to flight hardware was completed with favorable results and is expected to move to full implementation. The pilot program tracks FOD found during closeout inspections rather than during work activities. The premise of the program is that any debris found “upstream” of the closeout inspection is processing debris. There are measures and mechanisms in place to detect and eliminate processing debris. The pilot program provides management visibility to the debris that carries the most risk to the Space Shuttle Program. ◆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